SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (6) / 2. GOVT ACCESSION NO. AD-A098355	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Proceedings of Seventh Annual Acquisition Research Symposium (7th), Hershey, Pennsylvania 31 May - 2 Jun 78,	5. TYPE OF REPORT & PERIOD COVERED Final, 1978
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) N/A AD A098355	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Business Research Management Center Wright-Patterson AFB, OH 45433	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (12) 579
11. CONTROLLING OFFICE NAME AND ADDRESS Federal Acquisition Institute 726 Jackson Place, N.W. Washington D.C. 20503 (11)	12. REPORT DATE June 1978
	13. NUMBER OF PAGES 626
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Federal Acquisition Institute 726 Jackson Place, N.W. Washington D.C. 20503	15. SECURITY CLASS (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release: distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Approved for public release: distribution unlimited

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Contract Management	Reliability Incentives/Management
Contract Administration	Source Selection
Life Cycle Costing	Acquisition Strategy
Production Cost Estimating	Design-to-Cost
Contractor Motivation	Program Management

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Proceedings contains acquisition related papers which were presented during the Seventh Annual Acquisition Research Symposium held at the Hershey Motor Lodge and Convention Center in June 1978. The theme for the Symposium was "Working Tomorrow's Contracting and Acquisition Systems Today." The papers cover such areas as contractor motivation, production cost estimating, source selection, acquisition strategy, and competition.

PROCEEDINGS

Seventh Annual Acquisition Research Symposium

WORKING TOMORROW'S CONTRACTING

AND ACQUISITION SYSTEMS TODAY

HELD AT
HERSHEY MOTOR LODGE AND CONVENTION CENTER
HERSHEY, PENNSYLVANIA
(MAY 31 - JUNE 2, 1978)

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WORKING TOMORROW'S CONTRACTING

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FOREWORD

Employing research to improve the effectiveness and efficiency of the systems acquisition and support process has long been advocated. One of the recommendations stemming from the 1967 DOD Pricing Conference held at Hershey, Pennsylvania, dealt with the need for a Department of Defense Procurement Research Laboratory. A series of events and activities followed which endorsed the need and provided momentum for the concept.

In 1969 the Army Procurement Research Office was established and in 1970 the House Government Operations Committee concluded that there was a need for a procurement research laboratory for DOD. In 1971 the Department of Defense established a Procurement Research Coordinating Committee; and in 1972 the Commission on Government Procurement advocated establishment of a Federal Procurement Institute with responsibility, among other things, for conducting and sponsoring research in procurement policy and procedure.

The Air Force Business Research Management Center was established in 1973, and the Naval Center for Acquisition Research and the Federal Acquisition Institute were established in 1977. Also in 1977, the Defense Department issued a directive to formalize the Acquisition Research Program of the DOD and to coordinate its program with the Federal Acquisition Institute. The same year the General Accounting Office issued a report which called for establishment of a strong Government-wide program of procurement and acquisition research.

Beginning in 1972 the Department of Defense has hosted an annual symposium to share procurement research results among the academic, business, and acquisition management communities. From a modest beginning (12 papers), the Procurement Research Symposium has grown to 100 papers scheduled for presentation this year.

The title change of this seventh symposium from the DOD Procurement Research Symposium to the Acquisition Research Symposium reflects the broader scope and responsibility being accepted by the acquisition research community. Acquisition research is moving rapidly to be responsive to the needs of the total acquisition process and the applicability of the results throughout the Federal Government.

The theme of this year's symposium recognizes that research into the integrated contracting and acquisition processes should be responsive to both today's and tomorrow's needs and that tomorrow's contracting and acquisition systems rest in part upon knowledge developed by today's research.

The Hershey Pricing Conference in 1967 may be said to have initiated an era concerned with discovering and refining the concept of acquisition research. With dedication and insightful management, this "Return to Hershey" can begin an era where acquisition research becomes a participating factor in formulating tomorrow's contracting and acquisition systems.

The views expressed in this proceedings are those of the authors and do not necessarily reflect the views of the organizations with which the authors are associated.

Additional copies of the proceedings may be obtained by telephoning or writing:

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Building 125, Area B
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ACQUISITION RESEARCH WITHIN DOD

Within the Department of Defense acquisition research is performed by studying, reviewing, digesting, analyzing, appraising, or summarizing data or information related to the acquisition process. The purpose of acquisition research is to develop new or improved management concepts and more effective acquisition methods. The aim of acquisition research is to provide information of benefit to those responsible for identifying policy deficiencies and solving management problems in functional areas such as, but not limited to, requirements analysis and operational needs, engineering, development, planning, programming, budgeting, contracting, cost and price analyses, performance measurement, source selection, quality assurance, production capacity, test and evaluation, and adequacy of the support capability for the Defense acquisition programs.

An Acquisition Research Council (ARC) provides overall guidance to the acquisition research effort. The council is composed of:

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Office of the Under Secretary of
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Acquisition research elements responsible for conducting the DOD acquisition research program are:

Defense Systems Management College
Fort Belvoir, Virginia 22060

Army Procurement Research Office
Army Logistics Management Center
Fort Lee, Virginia 23801

Air Force Business Research Management Center
Wright-Patterson AFB, Ohio 45433

Naval Center for Acquisition Research
Naval Postgraduate School
Monterey, California 93940

PROCEEDINGS FROM PREVIOUS SYMPOSIA

972 - Proceedings, DOD Procurement Symposium: Progress and Research in the Seventies. School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson AFB, Ohio. 23-24 February 1972.

1973 - Proceedings, Second DOD Procurement Research Symposium: Procurement Problems - A Challenge for Procurement Research. Naval Postgraduate School, Monterey, California. 1-3 May 1973.

1974 - Third DOD Procurement Research Symposium Proceedings: Improving Procurement through Research. Army Procurement Research Office, US Army Logistics Management Center, Fort Lee, Virginia. September 1974.

1975 - Proceedings of the Fourth Annual Department of Defense Procurement Research Symposium: Doing Business in a Changing Society. United States Air Force Academy, Colorado. October 1975.

1976 - The Fifth Annual Department of Defense Procurement Research Symposium. Naval Postgraduate School, Monterey, California. 17-19 November 1976.

1977 - Proceedings of the Sixth Annual Department of Defense Procurement Research Symposium: Translating Procurement Research into Action. Army Procurement Research Office, US Army Logistics Management Center, Fort Lee, Virginia. June 1977.

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Lt Col Robert H. Hale, Headquarters United States Air Force
Representing: Directorate of Planning Programming and Analysis
Deputy Chief of Staff, Research and Development

INTRODUCTION

Managing modernization is the primary focus of our efforts within DCS/R&D. There have been a number of recent Air Force initiatives in acquisition management which have significantly influenced how we do that. Each of the two major areas, the resource allocation decision process, and the program initiation review process, have been and continue to be undergoing major changes. This paper will present results of the recent period of signficant development of new procedures and techniques in both areas.

First, the mission area planning, programming, and budgeting processes currently evolving are designed to ensure that programs are judged on the basis of validated mission needs and that scarce resources are allocated on the basis of a prioritized heirarchy of these needs. Development of this three step resource allocation decision process culminated in the preparation of the FY 79 Budget Estimate Submission and President's Budget. The tools and techniques used are the result of several years of hard developmental staff work and are the major "research" product of this paper. The pressure from Congress and others to present and defend our programs in a mission oriented structure no doubt helped keep our efforts going during difficult periods, but mission area planning and analysis is an idea whose time has come.

Another forcing function toward mission orientation was directed primarily at the individual system program initiation and decision process. OMB Circular A-109 and the implementing DOD Directives 5000.1 and 5000.2 require new programs to be conceived and approved, not from specific solution oriented proposals but from statements of mission needs. The source of these mission needs statements is again mission area analysis which identifies deficiencies in capability. This mission analysis may be done slightly differently at first, and be more detailed in its specific focus, but the same concerns and considerations for mission deficiency identification prevail. The second part of this paper will present the Air Force's implementation of these new policies and requirements for system program initiation and review.

Finally, the necessary interrelationship of these two major processes will be briefly discussed, to point out some problems involved in their ongoing integration, and an opportunity for future research into acquisition methods and procedures.

RESOURCE ALLOCATION DECISION PROCESS

This first major section of this paper, and the part which details the developed methodology, is the discussion of the Mission Area Planning activity used for resource allocation during the FY 79 Budget Estimate Submittal. During the preparation of that submittal, we applied the mission area planning process to the formulation of the Research, Development, Test, & Evaluation program for the Air Force. The relative success of this venture, and the greater understanding it provided, led to Air Staff-wide application of the methodology for the FY 80 Program Objective Memorandum cycle.

Mission Area Planning is a logical three part process composed of Mission Area Analysis, Development Planning, and Zero-Base Budgeting. The first part, Mission Area Analysis, is the technique used to define the problem(s) which the Air Force program should address, and is mainly an operator responsibility. Subsequent applications of the method will reflect this responsibility more strongly, with DCS/Plans and Operation leadership and heavy MAJCOM participation. The second part, Development Planning, is the segment which defines alternative solutions to the problem(s), and requires strong developer involvement, especially when the solutions involve RDT&E activity and funding. DCS/R&D lead is required with heavy participation by AFSC. Zero-Base Budgeting is the third part of the process, where we select affordable solutions from the defined alternatives. At the integrated formulation level appropriate to the Air Staff, this is really programming with fiscal constraints. Integration of the various parts of the total Air Force program is a significant challenge under any procedure, and we find the appropriate DCS/Programs and Resources and Air Force Comptroller leadership here. DCS/R&D handles the RDT&E, and the Air Force Board Structure plays a major role in integrating the total program. These three major parts of the process will be further broken down and described in the subsequent paragraphs.

Mission Area Analysis, which is used to define

the problem, is itself a basic three step exercise. The first step is to build a framework for the analysis, based on the missions which the Air Force must perform. The second step identifies deficiencies in the capability to accomplish those missions. The third step is to assess the overall mission area needs.

To build an appropriate framework, we must first break the total program, in this case the RDT&E program, into appropriate missions and mission areas. Each mission area is then further broken down into a matrix based on the functions which must be performed to accomplish the mission, and the conditions under which the functions will need to be performed. The conditions considered could be such things as the type of conflict, environmental considerations, or any other set of conditions which have the most significant impact on the conduct of the functions which make up the individual mission area.

A wide variety of possible mission area structure approaches are possible. The RD Mission Area Structure which we used has evolved over the past couple of years in response to the uses and needs it must serve. One objective of the structure we use is to group mission related programs together so reasonable trade-offs can be made and similar condition considerations are applied to the analysis of mission related programs. Our structure (see figure 1) has the same basic problem as most if not all other mission area breakouts, in that some functional areas apply across the mission areas and are difficult to place neatly into the mission framework. We put those functional areas of Technology Base and Management and Support along with the other across-the-board things like C^3 and Defense-Wide Systems.

FIGURE 1

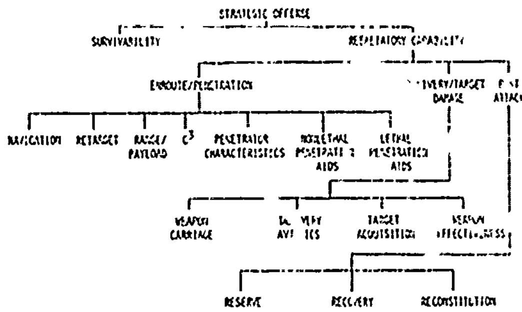
RD MISSION AREA STRUCTURE

STRATEGIC	GENERAL PURPOSE	SPACE	SUPPORT
• OFFENSE	• AIR SUPERIORITY	• LAUNCH/ORBITAL SUPPORT	• TECHNOLOGY BASE
• DEFENSE	• CAS/INTERDICTION		• C^3
	• RECONNAISSANCE		• DEFENSE-WIDE SYSTEM
	• AIRLIFT		• MANAGEMENT AND SUPPORT

These eleven mission areas are further broken down into major functions, tailored to each mission area, then even further to the lowest level of task or capability which is reasonable for that particular mission area. This detailed structure of the tasks and capabilities required in each mission area forms one side of a matrix for the mission area in question. An example will help to illustrate the point. Strategic Offense is considered to consist of two major functions or tasks, Survivability and Retaliatory Capability. See Figure 2. Retaliatory capability is likewise composed of three elements; Enroute/Penetration, Delivery/Target Damage, and Post Attack. Finally, in this example, Enroute/Penetration breaks down to seven more specific elements of capability required to have or generate strategic offense.

FIGURE 2

STRATEGIC OFFENSE



This example serves to illustrate the level of detail necessary to analyze the mission requirements and our capability and deficiencies in a meaningful way. These seven functional tasks are now arrayed, with the corresponding entries for the other portions of the Strategic Offense Mission Area, across one side of the Strategic Offense matrix.

The other side of the matrix, please recall, was to reflect the conditions under which the various functional tasks of the mission area are to be performed. These are unique to each mission area and should reflect the conditions which exert the most influence on the requirements and abilities to perform the functions, such as the type of conflict, environmental and visibility conditions, etc. In the Strategic Offense mission area, the type of conflict conditions of General War, Limited War, and Crisis are the most meaningful. Because these conditions affect the ICBM portion of our Strategic Offensive force so differently from the aircraft or airbreathing portion, we further divided each type of conflict condition into an ICBM portion and an aircraft portion. The condition side of the Strategic Offense matrix, therefore, has six elements.

There is now only one thing left to do to complete the framework for the analysis, and that is to assign importance weights to both the functional tasks and the conditions. Weights were assigned to the functional tasks based on how important each task is to mission

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accomplishment. The total of these weights for each complete mission area adds to 100. Weights were assigned to the conditions depending on how important the condition is as a basis for planning, and these weights add to 1.0. The allocation of both sets of weighting factors is developed by the mission area analyst with the support of the operations community. These provide an objective basis for determining the relative importance of various deficiencies and capabilities.

To again use the Strategic Offense mission area as an example, the conditions were assigned weights of 0.5 for general war, 0.3 for limited war, and 0.2 for crisis. More that these weights add to 1.0 because these three conditions are the only ones considered throughout the Strategic Offense matrix. As a strictly notational example of the functional task side of the matrix, the seven tasks could have been assigned weights ranging from 8 to 3 as shown in figure 3. These weights cover only a portion of the functional task side of the Strategic Offense matrix, and therefore add to less than the 100 total for the entire mission area.

FIGURE 3

SAMPLE MATRIX

TASK / CONDITION		RETALIATORY CAPABILITY						
		ENROUTE/PENETRATION						
		Navigation	Retarget	Range/Payload	C^3	Penetrator Characteristics	Penaids	
							Non-Lethal	Lethal
		5	3	8	4	4	5	4
GENERAL WAR 0.5	ICBM	G	R	Y		G	G	R
	AIR-CRAFT	Y	Y	Y		Y	Y	Y
LIMITED WAR 0.3	ICBM	G	R	Y		G	G	R
	AIR-CRAFT	G	Y	G		Y	Y	Y
CRISIS 0.2	ICBM	G	R	Y		G	G	R
	AIR-CRAFT	Y	Y	Y		Y	Y	Y

We have now completed building the framework for our mission area analysis, and are ready to go on to the second step in defining the problem, the identification of deficiencies. Each cell in the matrix we have built represents a combination of a functional task which must be accomplished and the possible conditions under which it must be done. To identify deficiencies in capability, we compared our capability at each cell of the matrix against the threat. Each of these comparisons could itself be the subject of a rather rigorous analysis, but for this purpose and time these comparisons were subjective judgements based upon objective criteria made by the individual analysts. Because of the subjective nature of these evaluations, only three categories of evaluation were used: inadequate, marginal, and adequate. For quickness and ease of understanding, these evaluations were represented by the colors red, yellow, and green, respectively. The matrices soon became refered to as stop light charts.

Deficiencies, of course, are time dependent since both our capability and the threat change over time. Our analysis for the FY 79 Budget Estimate submission considered pertinent time periods from FY 78 to FY 85. Future applications of the basic technique will probably look even farther into the future than that. Today's deficiencies are depicted by evaluating the FY 78 capability versus the FY 78 threat, and this serves as a baseline for later consideration. We also considered the impact on our capability if we made no further improvement or investment in the mission area, by looking at the FY 78 capability versus the FY 85 threat. Finally, we looked at the effect if we made no changes in the currently approved investment program by looking at the FY 85 capability versus the FY 85 threat. Each mission area thus yields a family of matrices with the the cells colored green, yellow, and red. The extent and location of yellow and red cells indicate the magnitude and nature of the deficiencies in the different time periods portrayed. Figure 3 shows , again, the notational example with colors indicated by the letters R, Y, and G.

We are now ready for the third and final step of the mission area analysis, and we have almost finished defining the problem. This last step is necessary because a deficiency along does not define a problem. We must also consider the importance of the deficiency times some measure of the importance of the capability found to be deficient. We also need to establish a quantitative way of treating the degree of deficiency which has been represented by the colors of red, yellow, and green. First, therefore, we assigned arbitrary numbers to the colors: 5 for red 3 for yellow, and 1 for green. Then, we went back to the weight factors assigned to the functional tasks and conditions to develop a qualitative measure of the relative importance of each cell of the matrix. For example, the Range/Payload function for the General War condition has a relative importance weight of 4 (8 x 0.5). It is now possible to determine a relative assessment of the degree of deficiency for each cell of the matrix by multiplying the deficiency score by the function importance weight and the condition weight. The absolute value of these numbers has no significance, but their relative size within the possible range for the mission area indicates the significance of the problem. The familiar notational example of the Strategic Offense matrix will illustrate. The high possible need score would be 20 (5 points for a red cell, times 8 for the most important

function weight, times 0.5 for the General War condition. The lowest need would have a score of 4. A marginal in Range Payload for aircraft under a General War condition would present a medium sized problem with a score of 12. See figure 4.

FIGURE 4

IMPORTANCE WEIGHT

CONDITION \ TASK		RETALIATORY CAPABILITY						
		ENROUTE/PENETRATION						
		Navigation	Retarget	Range/Payload	C^3	Penetration Characteristic	Penaids Non-lethal	Penaids Lethal
		5	3	8	4	4	5	4
GENERAL WAR 0.5	ICBM			Y / 9				
	AIRCRAFT			Y / 12				
LIMITED WAR 0.3	ICBM			[illegible] / 6				
	AIRCRAFT			6 / 2				
CRISIS 0.2	ICBM			Y / 9				
	AIRCRAFT			Y / 6				
				44				

In a very similar fashion, we can make an ove.-all assessment of the functional tasks by summing the need for the various functions over all conditions. This provides an indicator of the need for effort to be expended on the particular functions. Again, the number itself has significance only in relation to the possible range of overall function scores. Extending the previous logic to the functional task level for the Strategic Offense example, we get a possible range of 80 for a high need to 16 for a low need. The score of 44 for the Range/Payload task (figure 4) would be in the middle range and represent, again, a middle size problem overall in Range/Payload capability of our Strategic Offensive force.

We have now generated a comprehensive view of the needs which our development and investment programs should address. Deficiencies in individual functior under specific conditions are revealed as ell as overall functional shortcomings in a mission area under all conditions. The time sensitivity of needs can be seen, and the effects of our program progress assessed, as well as the effects of a changing threat represented by the progress of our adversaries. Areas where technology is needed in the longer term can be found, as well as the needs for specific system or subsystem development.

This completes the first part of Mission Area Planning, the Mission Area Analysis. Before I go on to the second part, Development Planning, I will discuss the modifications and extrapolations made in the mission area analysis procedure for subsequent Air Force-wide application. In its extrapolation to the overall Air Force problem, the methodology for the FY 80 Program Objective Memorandum and subsequent applications reflects a few changes. The scope of the analysis has been enlarged to include both a force size and a readiness analysis, in addition to the previous capability and R&D hardware analysis. The detailed matrix view has been abstracted into "increments of capability" to provide macro measures of "what" and "how much" to support the broader Air Force-wide application. This increased scope of mission area analysis allows a more comprehensive interface with all aspects of Air Force activity such as: (1) specialized analyses and long range planning; (2) changes to strategy and tactics, readiness and logistics, force structures, and equipment; (3) the front end of major systems acquisition; and (4) guidance to the planning, programming, and budgeting system. The interface with the front end of major systems acquisition will be discussed later in connection with the Air Force program initiation process. The interface with the PPBS provides the necessary transition into the second step in Mission Area Planning, called Development Planning for the R&D community.

The kind of Mission Area Analysis done for the FY 80 POM, provides the connecting link between the Planning in the PPBS and the Programming and Budgeting. Mission Area Analysis forms a bridge which brings the output of the Joint Strategic Planning System and the Development Planning System together. This merger generates the program submittals of the PPBS which ultimately result in force structure which Operational Planning deploys and employs. The initial cut at such a comprehensive Air Force-wide analysis was completed in December 1977, and was published as the Air Force Planning Guide. This document is the product of a thoroughly integrated and coordinated set of mission area analyses done at the MAJCOMS and in the Air Staff with mutual input from joint and interservice sources, DOD guidance and other available studies and analyses. The final integrated mission area analysis was formally coordinated with the commands and become the Air Force Planning Guide. It is the basis for the functional planning by the MAJCOMS and the Air Staff, such as Personnel Planning in DCS/Personnel, Development Planning in DCS/R&D, Logistics Planning in DCS/S&L, and Force Planning in DCS/Plans and Operation. This detailed functional planning and the associated programming during the POM perparation will result in the Air Force Program for the FYDP period FY 80-84. Ultimately that program, after review and decision by OSD, will be the basis for preparation of the Air Force Budget for FY 80. The Development Planning just mentioned is the same process which is the second part of Mission Area Planning as

we defined it at the beginn'ng of this paper, the part where we define alternative solution'. So whether the mission area analysis is done in the context of R&D and investment opportunities, or done Air Force-wide and provided as an input to the development community, it is still only the first of the three steps in the process. In reality, a significant amount of the detailed mission analysis we did for FY 79 will have to be done by the developers to provide the understanding needed for investment decisions.

Development Planning, the second step of the Mission Area Planning process, is where we define alternative solutions. Just like the Mission Area Analysis portion, it is composed of three logical steps. The first step develops viable alternatives for the various R&D programs. The second step assesses the contribution of each alternative to satisfying the deficiencies and needs previously identified. The third step builds development strategies for consideration by the decision makers in allocating resources.

In performing step one, we must first realize that for any deficiency there are several alternatives to consider. It could be that a change in tactics of deployment or employment would satisfy the deficiency, or perhaps a modification of existing systems would fill the need. Probably the least attractive alternative from a resource and time stand point is the development of a new system. However, for each deficiency which can and does require an RDT&E alternative, we define viable alternative programs to respond to the need. The technical content and schedule constraints which effect each of these alternatives are key considerations in determining which will be considered. This step was largely done in HQ USAF for the Budget Estimate Submission, but AFSC and field input will play heavily in the FY 80 POM and subsequent cycles.

Step two of the Development Planning process is to assess the value of each alternative. This assessment is based on two key considerations; the contribution the program can make to satisfying the need, and how important the need is. The importance of the need or problem is already represented quantitatively by the function task weights we determined during the Mission Area Analysis phase. During the Budget Estimate Submission, we used an approach which assigned a numerical value from 0 to 9 to the contribution each program element made to each functional task in the matrix. The value of the program element to each function is thus the function importance weight times the program element contribution, as shown in figure 5. The total for any given program element can then be assessed against the relative totals for competing alternative programs.

FIGURE 5

P.E. CONTRIBUTION

	RETALIATORY CAPABILITY						
	ENROUTE/PENETRATION						
	Navigation	Retarget	Range/Payload	C^3	Penetrator Characteristic	Terminal: Non-lethal	Terminal: Lethal
WEIGHTS	5	3	8	4	4	5	4
X							
CONTRIBUTION		6	5		6	2	
=							
ASSESSMENT		18	40		24	10	

With the assessment of alternative solutions in this quantitative relative sense, we can now conceive various possible fiscally reasonable, but still unconstrained development strategies. This is the third step of the Development Planning process building development strategies. Application of fiscal constraints comes next, but thats the final part of the Mission Area Planning process.

Tre FY 79 BES was the first use of Zero-Base Budgeting within the Air Force, but it caused primarily administrative burdens and did not significantly interfere with the next portion of the Mission Area Planning process, selecting affordable solutions. This portion consists of four steps. First, we group the program elements into decision units, then generate decision packages. Next, we formulate mission area investment strategies, and finally, we integrate the RDT&E program with the rest of the Air Force BES.

The first of these four steps is fairly easy and straightforward, but sometimes leads to consternation and disagreement. We must identify related groups of program elements to be grouped into something called decision units. This grouping is done in basically the same mission area structure we used for the analysis, but individual programs make contributions to more than one mission area and the allocation is not always as easy as it might seem. The objective is to make trade-offs easier and more meaningful among competing alternative programs to satisfy the same or related needs.

The second step is to generate decision packages. The packages each represent a possible alternative for the decision unit based upon a particular development strategy. In our familiar Strategic Offense example, their might be packages for a cruise missile strategy, an ICBM strategy, etc. This is an arduous and painfully iterative process which consumes far more time than the description of it would indicate. The decision packages must provide real choices in response to the needs and balance the contributions of the

programs to get high payoff from the resources involved.

The third step in Zero-Base Budgeting is to formulate mission area investment strategies. This step introduces fiscal constraints as we devise the best possible investment strategies based on the previously developed decision packages. In the ZBB environment of the BES, we formulated programs at three levels of funding. So far, it appears that the minimum level is probably the most important since it is most likely to be selected. Again, much iteration and consideration go into this step, for this is what determines the Air Force R&D program.

The fourth and final step in the Zero-Base Budgeting portion is to integrate the RDT&E program. This involves getting RDT&E bogies or overall funding levels at each of the three fiscal levels, and applying those constraints to the final make-up of each mission area program. Then, we provide the RDT&E solutions in each decision package to the functional elements elsewhere in the Air Staff. It is important to be sure that the RDT&E program is consistent with and supports the rest of the Air Force program. RDT&E will be driven by the top 1 overall Air Force objectives, and we work closely with the Program Review Committee and the rest of the Air Force Board Structure to ensure that consistency is maintained.

This completes the discussion of the resource allocation methodology using Mission Area Planning. Mission Area Planning has provided the logical basis for the program we submit and defend to OSD and the Congress, and which we will ultimately direct on the developers.

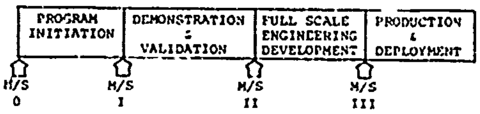
AIR FORCE PROGRAM INITIATION AND REVIEW PROCESS

The second major section of this paper deals with the program initiation and review process which has evolved in response to OMB Circular A-109 and the DOD Directives which implement it, 5000.1 and 5000.2 If the first major section of this paper on resource allocation can be thought of as the planning portion of the discussion, this section will be the implementation portion. This portion will discuss basically three subjects: Mission Element Needs Statements and the related requirements process; Air Force Designated Acquisition Programs and their review and approval processes; and the Air Force Systems Acquisition Review Council and its role and relationship to the Defense System Acquisition Review Council.

By way of review, lets take a quick look at the system acquisition life cycle, to be sure and understand the framework. There are four phases, similar to what they were in the past. First is the Program Initiation or Conceptual Phase, following MENS approval or Milestone Zero. Next, is the Demonstration and Validation Phase after Milestone I. After the Milestone II decision to spend really big dollars, comes the full-scale Engineering Development Phase. Finally, after Milestone III, the Production and Deployment Phase. Note that a time axis is not shown because the pace of progress through the phases will vary widely between individual programs. See figure 6.

FIGURE 6

SYSTEM ACQUISITION LIFE CYCLE



The primary focus of DODD 5000.1 and 5000.2 is the formalization of the front end of this acquisition process. The key element in that formalization is the Mission Element Need Statement. This statement is used to document the deficiencies and needs which can be expected to lead to a major system acquisition program. It is presented by the Service to the Secretary of Defense for a Milestone Zero decision to pursue a solution to the need. The need expressed in the MENS will be reviewed, reevaluated and revalidated at each subsequent milestone decision point.

We have developed the concept of a companion, Air Force level document called an AFMENS. The AFMENS also documents a deficiency or a need, but one which can be expected to lead to an acquisition program conducted solely with Air Force level decisions. Milestone Zero approval would be a Secretary of the Air Force decision, and the resulting program would be called an Air Force Designated Acquisition Program (AFDAP). Again, the need would be reviewed, reevaluated and revalidated at each subsequent milestone, but the milestone reviews and decisions would be made at Air Force rather than OSD level.

Determination of which of these two documents is appropriate, a MENS or an AFMENS, is based on a subjective consideration with only general criteria. When the anticipated program impact is broad, highly significant nationally, and major in scope, the OSD level MENS is probably the appropriate document. If the impact of the anticipated program is more purely Air Force, but still large in scope, the AFMENS is likely the proper choice. Dollar thresholds are

difficult to apply since the needs are not supposed to be solution oriented, but the major program thresholds formerly used of \$50M RDT&E and/or \$200M procurement provide an order of magnitude guideline that at least an AFMENS should be considered.

Here is an outline of the key items which will be incorporated in either MENS or AFMENS prepared by the Air Force. Keep in mind that the MENS or AFMENS is a needs oriented document, not a requirements document. It should state clearly what the deficiency or needed capability is in mission terms and not be a solution description with specific performance parameters for hardware.

FIGURE 7

MENS AND AFMENS CONTENT

MISSION
- Mission Area
- Mission Element Nec. Task

THREAT
- Projected Threat
- Intelligence Agency Input

EXISTING AND PLANNED CAPABILITIES
- DOD and Allied
- Multi-Service

ASSESSMENT
- Deficiency in Existing Capability
- Technological Opportunity
- Force Size and Physical Obsolescence
- Vulnerability of Existing Capability

CONSTRAINTS
- Affordability
- Priority
- Logistics
- NATO Standardization/Interoperability
- Timing of the Need

IMPACT OF STAYING WITH PRESENT SYSTEM(S)
- Ability to Meet Projected Threat
- Cost of Increasing Quantity of Existing Eq.
- Cost of Maintaining Existing Eq.

RESOURCES AND SCHEDULE TO MEET MILESTONE I
- Procurement Strategy
- Organizational Relationships
- Technological Areas to be Explored
- Cost
- Schedule

The approval of a MENS or AFMENS and a Milestone Zero decision is really the culmination of the requirements process as it is being conducted by the Air Force at the present time. The process begins with the preparation of a Statement of Operational Need (SON), normally by the operating MAJCOM. This SON replaces the old Required Operational Capability (ROC) document and reflects the same concentration on needs rather than requirements that characterizes the MENS. The SON derives from the awareness of a need by the operator, based on mission area analysis, a life cycle cost analysis, some technological opportunity, etc. The Air Force Planning Guide, which results from the Air Force-wide mission area analysis, is a key input to this awareness.

The originator sends a draft of the SON to AFSC and AFLC Headquarters, and any others who are appropriate for comment. The Draft Threat Assessment is sent to HQ AFSC (Intel). When comments have been received from these parties, the originator revises the SON as necessary and sends it to HQ USAF, with copies to the MAJCOMS and others. Recipients of the SON send their comments to HQ USAF also, to complete this part of the SON cycle.

The SON and all the related MAJCOM comments are received at HQ USAF by the Requirements Review Group (RRG) Secretariat, who refers it all to an R&D action officer for initial staffing and review. If it is determined that it is not appropriate to turn the SON into a MENS, the SON will be processed through the Requirements Review Group for validation and approval, just as the former ROCs were. If, however, a MENS is recommended, a MENS Planning Group, made up of action officer level representatives of the RRG member organizations, will evaluate the SON and develop a plan for generating a MENS. Actual preparation of the MENS will be by an Air Staff team led from the operations side with heavy intelligence and R&D participation. The MENS will ultimately be processed through the RRG just as the SON was. After validation by the RRG, the MENS will be processed through the Air Staff and the Air Force Acquisition Executive (SAF/AL) to the Secretary of the Air Force for decision. He may approve the document as an AFMENS, forward it as a MENS to the SECDEF through the Defense Acquisition Executive, or disapprove the document and either terminate the effort or send it back for further work. Should he approve it as an AFMENS, a copy of the document will be provided to the Defense Acquisition Executive who can always require OSD review. This total process takes approximately 210 calendar days. Field and initial staff comments are received during the first sixty days. Following preparation of the MENS, OSD, OJCS, field and other Service comments are solicited. The RRG review constitutes basic corporate senior management review, prior to submittal for decision at the Secretariate level. Milestone Zero decision completes the requirements process and our discussion of MENS and Milestone Zero. The next subject is Air Force Designated Acquisition Programs or AFDAPS.

Air Force Designated Acquisition Programs, AFDAPs, are a special category of system acquisition programs, for which Secretary of the Air Force level milestone decisions are more appropriate than Secretary of Defense level decisions. In our previous discussion about MENS and AFMENS, if the Secretary of the Air Force had decided, based on the earlier subjective criteria, to approve the need statement as an AFMENS, the ensueing program would be an AFDAP. An AFDAP is still

a major effort with significant impact of Air Force capability. It is expected to remain below the "major" program thresholds of \$75M RDT&E or \$300M procurement. AFDAPs will replace the previous Program Memorandum programs, but the OSD staff will be kept informed of progress and decisions of interest to them. With the introduction of AFDAPs, the Air Force will have three levels of programs from a management viewpoint; major systems with SECDEF milestone decisions; AFDAPs with SECAF milestone decisions; and non-designated programs which are less than major system and for which milestone decisions will normally be delegated to AFSC.

The review and approval of AFDAPs brings us now to the subject of the acquisition review process and the Air Force System Acquisition Review Council and Defense System Acquisition Review Council. Both the AFSARC and DSARC serve as executive corporate advisory bodies to their respective Secretaries. Both are chaired by the respective Acquisition Executive: the AFSARC by the Air Force Acquisition Executive, SAF/AL; and the DSARC by the Defense Acquisition Executive, USDRE. The AFSARC membership includes key SAF and Air Staff principals, while the DSARC includes key OSD staff principals. Key OSD staff principals are invited to AFSARC meetings of interest almost as a matter of course. The AFSARC reviews major systems prior to DSARC review, as well as AFDAPs for Air Force milestone and status review. It is envisioned that the AFSARC can review major programs prior to SECDEF decision and thus preclude the requirement for DSARC review. The DSARC is required to review major programs in the strategic, nuclear, intelligence, joint-service, C^3, or multi-national areas at Milestone I. It will review only the major programs designated by SECDEF at Milestone II and III. Non-military DOD programs will also be reviewed by the DSARC.

The system acquisition review process itself is an orderly series of reviews and coordination cycles which depend on a document called the Decision Coordinating Paper (DCP). The DCP, or Air Force DCP for AFDAPs, is the data base used throughout the coordination and review process at Milestones I, II, or III. The review process itself begins with a DCP planning conference where representatives from each of the key activities meet to set up a specific schedule of events and target dates for the remainder of the process. The objective of this conference is to organize the process and ensure that all the necessary data inputs are made available at the start of the briefing and review cycle. These inputs include, as applicable, the Independent Cost Analysis, Development Test and Evaluation (DT&E) report, Operational Test and Evaluation (OT&E) report, and the production readiness report. One of the tasks of the key players is to see that these and other critical inputs are available before the first corporate review leading to AFSARC/DSARC.

Following review by the AFSARC, the Secretary of the Air Force will make a milestone decision for AFDAPs, or forward the DCP up the chain through the Defense Acquisition Executive to the DSARC for a milestone decision by the SECDEF. Regardless which Secretary makes the milestone decision, it is documented in an Action Memorandum to the Air Staff. Action Memos issued by the SECAF are also forwarded to the Defense Acquisition Executive (DAE) for information. At his option, the DAE may request that a SACAF milestone decision be held in abeyance pending review by the DSARC. Finally, actual implementation of a Secretarial decision is accomplished by the Program Management Directive issued to the field by HQ USAF.

This total process takes takes approximately 180 days. The schedule is structured to ensure that all documentation and coordination is completed prior to the start of the briefing cycle.

INTEGRATION OF THE RESOURCE ALLOCATION AND PROGRAM DECISION PROCESSES

The first two major portions of this paper have dealt with related separate aspects of Air Force acquisition. The integration of those two aspects has been, and will continue to be a problem area. The resource allocation process which is described in this paper has been developed to provide a mission oriented rational to the development of the Air Force program in the PPBS cycle. On the other hand, the program initiation and decision process deals with the generation and continuation of any individual major acquisition program which would be a part of that overall Air Force program. It is obvious that actions in either of the processes can have a direct effect on the options and activity in the other. There is today little, if any, established regimen that ties the two together.

From the beginning of the planning cycle to the end of the execution of any fiscal year program is a time span of about four years. That the PPBS system stretches any given year's cycle that far is logical and understandable, but the result is still a problem. At any one time, there are three or four different FYDP programs in various stages of preparation and review. Thus, there is an almost constant source of uncertainty and instability in individual acquisition programs which is totally unrelated to anything within the programs themselves. Also a problem, is that each of these FYDP programs is undergoing

perhaps its greatest changes in the year just prior to execution, during the enactment cycle in the Congress. On other hand, the lead time to influence the content of any fiscal year's FYDP program is never less than nine months and can be a much as two years. The implications of this on a milestone decision are significant. After Milestone Zero approval, the only way to fund a new start during this lead time period is be reprogramming funds from some other program. The same is true of adjustments desired at any other milestone point in a program. Here again, during the enactment year, that year's FYDP program is unavailable to the Air Force for adjustment or modification in response to individual program decisions or problems.

The introduction of Mission Area Analysis to the resource allocation process, and the concentration on mission requirements in the program initiation process, are introducing a common element to the two activities. Mission Area Analysis seems the best hope for providing a tie between these processes. Just how to apply the techniques and tools to achieve the necessary consistency of direction and decisions deserves considerable attention. That challenge is perhaps the single most important focus for continued policy and procedure development in this area of acquisition research.

CONCLUSION

This paper has concentrated on the Mission Area Analysis tools and techniques developed to support resource allocation decisions in the Air Force RDT&E program. Subsequent applications of similar methodology to the Air Force-wide resource allocation problem, and to the development of need statements for individual program initiation have also been covered, but less thoroughly. All of these aspects of acquisition are undergoing change in response to new policy initiatives external to the Air Force, as well as to the commitment within the Air Force to approach system acquisition and resource allocation from a strongly mission oriented viewpoint. Considerable need exists for continued development of innovative policies and procedures to further enhance this mission orientation, to provide better resource allocation decisions, and to smooth the system program initiation and decision process. A special and more urgent challenge is to find ways to improve the ties between the PPBS and the system acquisition cycle.

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DETERMINING VALUE: A PROCESS FOR QUANTIFYING SUBJECTIVE BELIEFS

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INTRODUCTION

Over the past decade, the world of military procurement has moved from an environment constrained by technology to one constrained by available resources. In this climate of decreasing resources, acquisition managers are facing increasing pressure to provide more rational justification for their programs and to make m... efficient use of their resources. It would appear that the best strategy for dealing with these pressures is to develop as objectively as possible an estimate of the relative values of the programs and activities under the manager's control and to use these estimates to make better allocation of resources, both manpower and dollars.

The defining of value within his organization is a function every manager performs to some extent; the very act of setting priorities and allocating resources essentially defines what is valuable and what is not. In order for these values to be rational and justifiable, they must be logically derived from the organization's mission and in a manner that is comprehensible to others, both internal and external to the organization. Moreover, the organization's values must be communicated to its members so that they may better plan for and justify the particular programs for which they are responsible.

During the past few years, the theory of analytic hierarchies has been developed and applied to many different areas of multicriteria decision making [1], [4], [6], [7]. The methods of this theory are used to elicit from decision makers quantitative estimates of the values they intuitively use when making decisions; values they have built up from past experience. We have recently applied this theory to several decision situations within a DOD material acquisit n organization and we are briefly reporting : re the results of one application made in the area of resource allocation. Generalizing from this experience, we describe a process which organizations having similar structure and management style can use to estimate the relative values of their programs and activities.

COMPARISON MATRICES

A ke element in the theory of analytic hierarchies is the use of comparison matrices. They provide a method for obtaining estimates of the relative values of n items from a matrix of estimates of the ratios of these values. To begin, a person or group of persons are asked to compare the items two at a time and to give a numerical estimate as to how many times more valuable one is than the other. This gives a matrix A of pair-wise comparisons of the n items. Theoretical considerations indicate that the relative values of the n items inher... in the comparisons are estimated by the coefficients $x_1, \ldots, x_n$ of the eigenvector $\bar{X}$ corresponding to the maximum eigenvalue λ of the matrix A. That is, $\bar{X}$ is the (normalized) solution to the equation $A\bar{X}=\lambda\bar{X}$, with λ maximal. See [3] and [5] for the technical details of this and other aspects of analytic hierarchies.

Example: An experiment was conducted in search of a relationship between the illumination received by four identical chairs, C_1, C_2, C_3, C_4, placed on a line at distances of 9, 15, 21 and 28 yards from a light source. Judges were asked to compare the illumination of the chairs pair-wise, producing the following comparison matrix:

	C_1	C_2	C_3	C_4
C_1	1	5	6	7
C_2	1/5	1	4	6
C_3	1/6	1/4	1	4
C_4	1/7	1/6	1/4	1

The normalized eigenvector corresponding to the maximum eigenvalue of this matrix produced relative illumination values of the chairs of 0.61, 0.24, 0.10, 0.05, respectively. It is well known that the illumination varies proportionally with the inverse square of the distance. The normalized vector of inverse squares of the distances of the chairs to the light source is 0.607, 0.219, 0.112, 0.063. We have had similar accuracy of results in other experimental applications of this method to situations where the "answer" could be determined by objective measures [5], [6].

AN APPLICATION

A Budget Review Board in the subject organization was formed and charged with the responsibility of recommending the priorities to be placed on programs being included in the

organization's budget proposal. The Board obtained its information about the various programs under consideration via written justifications and oral presentations by the program managers. T. Saaty of The Wharton School and the author worked with the Board to test the applicability of analytic hierarchies to their problem.

The Board was first asked to define the primary purpose for prioritizing the programs under review. After considerable discussion, it was decided that the fundamental purpose was "To maximize the organization's contribution to the improvement of field operational readiness and capability." As it stood, this purpose was so broad that it was of little help in establishing preference between any two programs. However, to people experienced in the material acquisition process, this objective has enormous implicit informational content. The objective of the exercise was to extract this content from the Board members. Taking this broad objective as its apex (the top level of the hierarchy), a downward branching hierarchy of sub-objectives and factors was developed until a level of detail was reached that was considered to be operationally useful for setting priorities (Figure 1). Simultaneous weighting of the branches made it possible to keep the process tractable by "pruning" those branches with low weights.

Program Management and Project Management were determined to be the most important factors contributing to the fundamental objective. Since the organization dealt primarily with programs rather than projects, it is not surprising that project management was given a low weight. Consequently, only the Program Management branch was developed further. Because of time constraints, it was also decided to concentrate only on New Programs. It was decided that the most important dimensions along which New Programs should be evaluated were:

- -Improvement of Existing Materials
- -Development of New Materials
- -Development of New and Improved Systems
- -Cost Savings

A comparison matrix for these four factors was constructed by the Board, producing relative weights of 0.48, 0.08, 0.29, 0.15, as indicated in Figure 1. Because of their low weight, Development of New Materials and Cost Savings were dropped and only the two remaining branches developed further. Improvement of Existing Materials branched into:

- -Reliability and Maintainability
- -Survivability
- -Mission Effectiveness
- -Producibility
- -Operational Feasibility

A comparison matrix of the relative impacts of these five factors upon the Improvement of Existing Materials was constructed, yielding the weights shown in Figure 1. Development of New and Improved Systems branched into:

- -Personal Safety
- -Training
- -Operational Efficiency
- -Fleet Requirements

Similarly, a comparison matrix for these factors was constructed, producing the weights shown in Figure 1. The lower weighted factors were dropped from the initial hierarchy and the weights of the remaining factors were renormalized to produce the final weighted hierarchy shown in Figure 2. For example, since the relative weights of Improvement of Existing Materials and Development of New and Improved Systems were 0.48 and 0.29 within their level of the initial hierarchy, their relative weights in the final "pruned" hierarchy should be:

$0.62=0.48\div(0.48+0.29)$ and $0.38=0.29\div(0.48+0.29)$

Each relative weight of a final criterion shown at the bottom of Figure 2 is the product of all the weights of the segments of the branch containing that criterion.

Because of time constraints, the Review Board was unable to carry out the next steps described below. However, they actively used the criteria in their deliberations over program priorities and in their justification of the priority rankings they finally recommended.

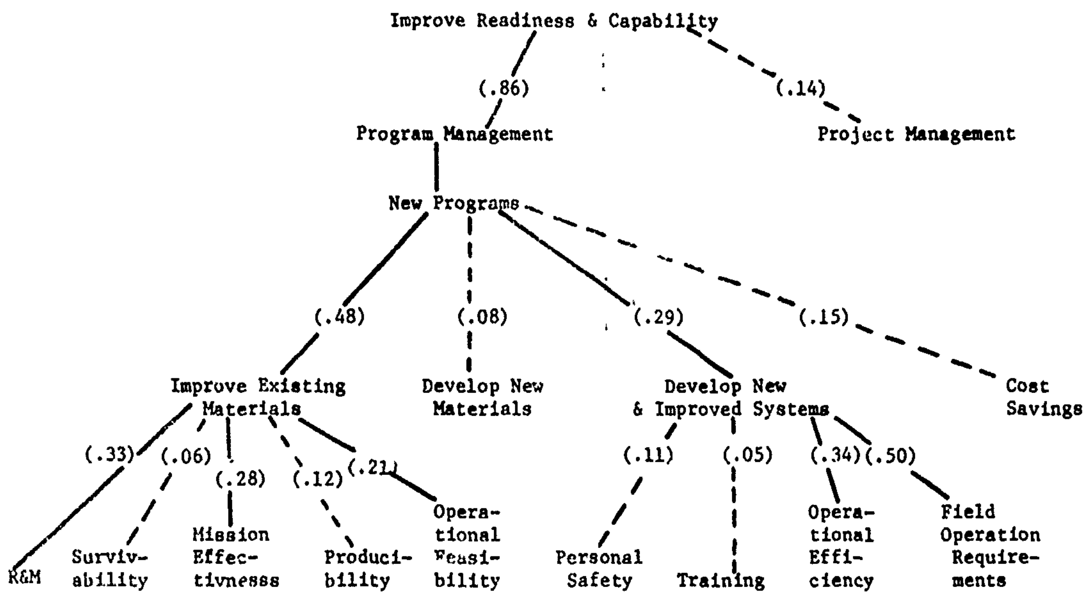
The next steps of the general process will be exemplified by a hypothetical situation. Suppose there are four programs A, B, C, D under consideration. Using each criterion in turn as a dimension of comparison, a comparison matrix for the four programs is constructed. For example, suppose the comparison matrix of the four programs relative to the criterion of Reliability and Maintainability were

R&M	A	B	C	D
A	1	1	3	2
B	1	1	4	3
C	1/3	1/4	1	1
D	1/2	1/3	1	1

An eigenvector of this matrix is used as before to estimate the relative values of the programs vis a vis the criterion under consideration (as shown in Table 1). The final relative value of a particular program is obtained by taking the weighted average of its values with respect to the individual criteria, e.g., the overall value of .31 of program A is:

$.25x.32+.21x.23+.16x.21+.23x.44+.15x.35.$

FIGURE 1



a. The numbers in parentheses indicate the branch weight.
b. The dashed lines indicate branches that were dropped from further consideration.

FIGURE 2

Final Hierarchy

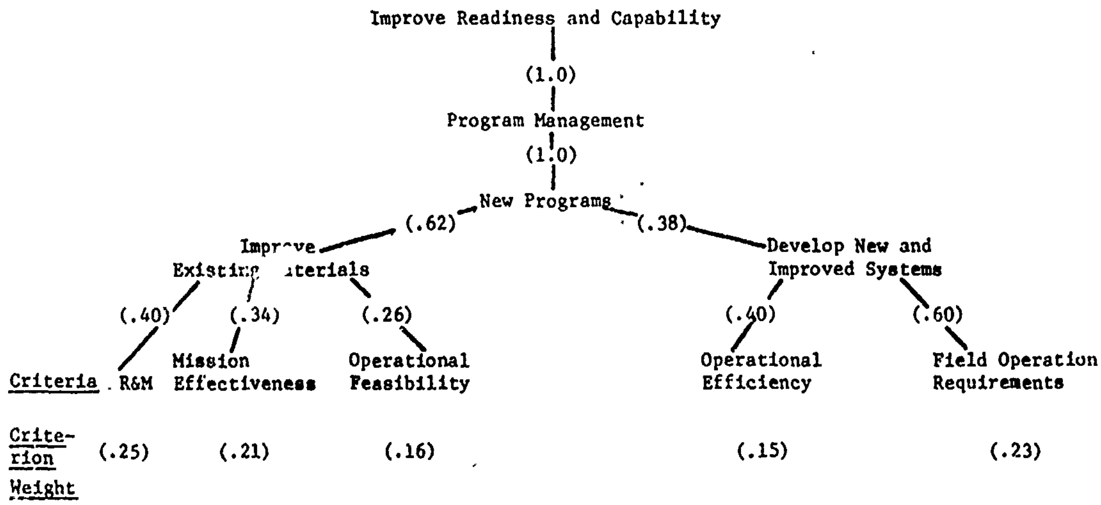


TABLE 1

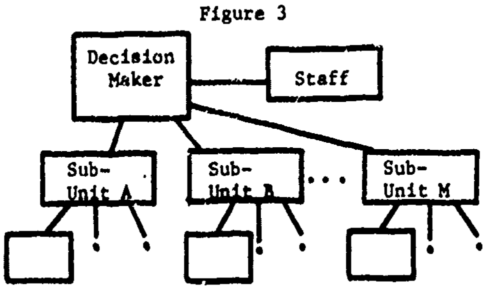
Program	Criterion-Specific Relative Values R&D (.25)	Mission Effectiveness (.21)	Operational Feasibility (.16)	Operational Efficiency (.23)	Field Operation Needs (.15)	Overall Program Value
A	.32	.23	.21	.44	.35	.31
B	.41	.27	.15	.21	.32	.28
C	.12	.31	.29	.26	.12	.22
D	.15	.19	.35	.09	.21	.19

From the table, the rank ordering of the programs by value should be: A, B, C, D. If this rank ordering were all that was known about the value of the programs, the normal decision rule for funding would be to fund all of A, all of B, and so forth until the budget limit was reached. Programs lying below this cut-off point would not be funded. However, if the relative values of the programs are known, as given in Table 1, the above rule does not in general produce the best possible allocation decision. For example, assume the estimated costs of A, B, C, D are $3.25, $2.75, $2.50, $.75 (in millions) and the total allowed budget is $6 million. Then the stated decision rule would fund A and B, and drop C and D, producing a package whose total value was .59. From the table, it is clear that one could obtain the total value of .69 by funding programs B, C, D. The funding rule to be used in the case where relative values are known is discussed in more detail in a later section.

THE PROCESS

It is assumed that the organizations for which our process is designed have the general structure of Figure 3. It is further assumed that the management style is consensus seeking, top-down decision making based on completed staff work.

Figure 3



The organizational process we describe here is broken into two stages. The first stage is the development of an organizational "value structure": a set of weighted decision criteria. The second stage is the estimation of program values based on the value structure.

Complex decision systems, both natural and artificial, have value structures which enable them to make decisions. The value structure of a natural system apparently develops through chance and natural selection, while that of an artificial system is built in by the system designer who extrapolates the structure from the fundamental purpose(s) for which the system is to be used [2]. The latter is the approach taken here. Although subject to periodic review and adjustment, the value structure is to be organizational policy that is relatively stable over time, and the extensive effort required to produce the structure need not be repeated annually.

The first step is to carefully construct the hierarchy that is to produce the criteria. Lists of potential criteria are elicited from the sub-unit managers, the decision maker and others. The staff consolidates this information and formulates one or more hierarchical breakdowns of the mission statement compatible with the level of detail and intent of the solicited criteria. It is important that these hierarchies are not mere reflections of the organization's structure. If a set of criteria is developed such that one criterion applies primarily to sub-unit A's programs, another to sub-unit B's programs, etc., it will be difficult to attain consensus as to whether one particular criterion is more important than another. Parochialism cannot be avoided entirely but its effects should be minimized on the basic value structure. A draft hierarchy is selected by the decision maker and circulated to the sub-unit managers for their comment. After considering these remarks, the decision maker approves the final hierarchy and its criteria (Figure 4).

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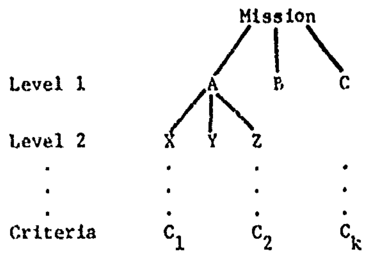
Figure 4



The second step is the actual weighting of the criteria. Progressing level by level down the hierarchy, blank comparison matrices are circulated to the sub-unit managers and others involved in the process who are then to fill in their estimates of the ratios involved. For example, referring to Figure 4, there would be a matrix circulated of the form:

A	X	Y	Z
X	1	*	
Y		1	
Z			1

The personnel involved would be asked to place in the box marked with the asterisk their estimate of the ratio of the importance of factor X to that of factor Y in achieving factor A. These matrices would be analyzed by the staff. If there are major differences of opinions, the conflicting parties would be asked to prepare justifications supporting their positions. (We have found that differing perceptions of the meanings of the factors being compared is a frequent cause of disagreement.) The average branch weights and the position papers are used by the decision maker and his immediate staff when making the final determination of weights. This final weighting process should take place during a two or three day planning retreat. The final value structure is communicated to the organization and higher authority as a statement of policy.

The second stage is that of estimating the relative values of the programs themselves (or decision packages if one is working in a zero-base budgeting context), and is to be carried out annually during the POM cycle. Criterion by criterion, the programs are compared against one another to produce their criterion-specific relative values. The weights of the criteria are then used as previously shown to "glue" these criterion-specific values of the programs together to produce a single valued estimate of relative worth.

The first thing to be settled is which programs are at the appropriate level for evaluation by the decision maker. The programs must be sufficiently broad so as to allow adequate decision making power to the sub-unit managers. For hardware programs, the work breakdown structure should provide a guide, but the problem will be more difficult for such "improve the system" tasks as "modernize the approach to specs and standards" or "revise costing procedures." The next step is to weight the programs relative to the criteria of the value structure. This would be carried out by the staff or a specially formed committee during the POM process. However, carrying out the process on all programs could be a monumental task. Even if the number of criteria were few, a large number of programs (or decision packages) could prove overwhelming. Two comments are in order here. First, on-going programs would only need to be updated; comparison matrices from the previous year could be re-examined and modifications made to only a few entries. However, new programs would still have to be weighted relative to themselves and the on-going programs. Second, in a marginal analysis budgeting process, such as ZBB, only those programs in the neighborhood of the cut-off point need to be carefully valued. The rankings of the very high priority and low priority programs could be determined by other, less time consuming means.

THE ALLOCATION DECISION

While the estimated program values produced by this process will not be sufficiently accurate to allow for a straightforward application of mathematical optimization techniques, it is nevertheless useful to discuss the theoretical consequences of such an application. If there are n programs (or decision packages) P_1, P_2, ..., P_n having estimated values $v_1, v_2, \ldots, v_n$ and estimated costs $c_1, c_2, \ldots, c_n$, one should fund that portfolio of programs having maximal value among all those whose cost does not exceed the funding constraints. Assuming that the value of a portfolio is the sum of the values of its members, one is led to using linear programming to determine the optimal portfolio. If the decision on each program is to either fund or not fund, integer programming would apply. If some of the programs could be partially funded (and linearity of value received with respect to funding level held), mixed integer programming would be used. There are two important implications of these remarks.

1. The values v_i can be taken to be the relative values ($\Sigma v_i = 1$) rather than the

"actual" values of the programs.

2. The general rule of thumb for setting funding priorities on programs is to rank them by their efficiencies v_i/c_i rather than their values. That is, the programs should be funded in the order $P_1, P_2, \ldots P_n$ where $v_1/c_1 \geq v_2/c_2 \geq \ldots \geq v_n/c_n$. This decision rule will produce a good approximation of the optimal portfolio. This is important because it is the decision maker who controls the numerator v_i while the sub-unit manager controls the denominator c_i. If the program manager clearly understands this funding rule he will try to convince his superior to increase the program value (hopefully by better justifications) and will tend to be more efficient by minimizing program costs (strict rules concerning cost overruns must be enforced here).

CONCLUSION

Since the majority of this paper has been devoted to describing the mechanics of the process, some space should be devoted to a discussion of its behavioral and motivational aspects. Through the use of logically derived hierarchies and systematic pair-wise comparisons, the process provides a truly holistic approach to planning. Consequently, it produces a surprising degree of consensus among its participants. Nor does it only drive towards consensus; it also clarifies the remaining points of disagreement to such an extent that the participants have a clear understanding of where others stand and why. There is a high potential for team building inherent in the process. This is why the final planning retreat with the decision maker and his immediate staff is so important. A major behavioral objective of the retreat is the development of a top-management team having a shared understanding of values and who can communicate and logically justify these values with one voice to others within and without the organization.

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OMB BULLETIN A-109; ZERO BASED BUDGETING; MANAGEMENT BY OBJECTIVES--SOME INTEGRATING CONCEPTS

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INTRODUCTION

Acquisition managers in the Department of Defense face a world of expanding technical complexity, shrinking resources, increasing mission needs, and more detailed public accountability.

In pursuing the legitimate objective of managing the Defense effort in this environment, top management institutes such disciplines as are defined by Office of Management and Budget Bulletin A-109, Zero Based Budgeting and Management By Objectives.

How does the acquisition manager cope with the bewildering environmental complexities and the seemingly disjointed and conflicting array of demands and acquire new weapon systems (as the text books say) in an effective and efficient manner?

This paper examines the acquisition process from the viewpoint of theory and concepts. There are many ways of looking at this process; some are better than others. The viewpoint outlined herein may provide a more scientific and better understanding of the acquisition process and thereby promote better acquisition management.

OVERALL APPROACH

Peter Drucker points out that the only product of managers (Government and otherwise), and their supporting staffs, is information which transmits the decisions of the manager to workers who use that information to produce and deliver the goods and services. Thus, an overall concept which integrates the acquisition process, OMB Bulletin A-109, Zero Based Budgeting and Management By Objectives, is the consideration of all of these disciplines as decision processes which generate information. This paper does not discuss the vital "doers" who produce goods and services used by the operating commands, but is limited to examining the hierarchy of management decisions which direct the "doers."

It is assumed to be self-evident that it is the objective of each manager, at all levels of an organization, to make those decisions which will result in providing the operating command with the "best" weapon system from the myriad of alternatives which exist. It is probably the understatement of the day to observe that each acquisition manager must perform in a complex, dynamic and unstructured world. In order for the manager to make rational decisions, he must collect and organize unstructured data into information which allows the comparison of the available alternatives upon some common basis. Based on this structured information, he must make his decisions (choices) and transmit these choices to his subordinates as information to guide their subsequent choices. Thus, not only does management generate information to transmit their decisions to workers, but also, higher level management must provide information which transmits their decisions to the lower levels of management.

This paper suggests that improving the acquisition process requires a definition and understanding of the nature and content of the decisions which must be made as the prerequisite to defining who (the organization or individuals) should be assigned the responsibility for these decisions or how (the processes or procedures used) the decisions should be made. Thus, this paper is limited to "what" decisions must be made rather than the "who" or the "how" of the decision process.

DISCUSSION

In order to illustrate the concepts outlined in this paper, an example is considered in the discussion which follows. This example is grossly simplified but is representative of one of the kinds of problems which face the acquisition manager. This example illustrates the structuring of data in a manner which will promote the rational choice of the "best" weapon system. This example structures data utilizing relationships based upon engineering principles and statistical evidence where available. Where such relationships have not been established, they are assumed. The assumptions and numerical values used in this example have no significance other than to illustrate the concepts presented in the paper.

Assume the Navy needs expanded capability to provide logistic support to its carriers. Further, assume that, of the alternate means available, an analysis has established that the most cost effective system that can be provided to satisfy this needed capability will be an inventory of 100 aircraft which can land aboard the large carriers. Based on analysis, the Mission Element Need Statement (MENS) defines the following needs and constraints:

Maximum range at which logistics must be delivered - 3,000 n. miles

Annual payload delivery capability at 3,000 n. miles - 1 500 X 10^6 lbs.

Maximum system life cycle cost - $7.5 billion

Maximum annual RDT&E cost - $150 million

Initial operating capability - January 1986

With the need as defined by the MENS, the acquisition manager may then determine operational assumptions and design constraints, and objectives:

Constraints:

Maximum take-off gross weight (acceptable for landing on a carrier) - 50,000 lbs.

Aircraft life (assumed) - 20 yrs.

Average peacetime utilization (assumed) - 30 flt. hrs./mo.

Objective:

Maximum logistic delivery capability for the minimum life cycle cost.

With above assumptions, constraints, and objective, the acquisition manager may then request proposals from industry. For this example, assume the propulsion system is Government Furnished Equipment and the manager procures the propulsion system from one contractor and the remainder of the aircraft weapon system (defined as the airframe in this example) from another.

In order to keep the example extremely simple, assume the manager has the following weapon system alternatives:

Continue purchasing an existing airframe configuration - Configuration A

Develop and purchase a new airframe configuration - Configuration B

Continue purchasing an existing propulsion system - Configuration 1

Develop and purchase a new propulsion system - Configuration 2

Combinations of the above

Table I shows the characteristics of the airframe and propulsion systems available. Inasmuch as each alternate considers events which will occur in the future and there is risk associated with achieving each characteristic listed. This risk is defined as (1-P), where P is the probability that the quantitative value listed will be achieved. In order to quantitatively consider risk the expected value of each characteristic is calculated in Table I as the estimated value either multiplied by P or divided by P (it is always assumed that risk makes the expected value "worse" than the estimated value).

In this extremely simplified example, it is also assumed that experts have validated that all of the values in Table I are the best estimates available and futher that all key program milestones are satisfactory in relationship to the required operating date.

The problem presented to the acquisition manager at this point is how to choose the "best" airframe-propulsion system combination for the Navy. However, because of the fact that no single airframe or propulsion system exhibits all of either the good characteristics or all of the bad ones, the manager must put weighting factors on each characteristic in order to select the best weapon system.

Table II shows some parameters which are considered to be significant to the user (and the acquisition manager) of the weapon system and the variable from Table I which determines the values of each of the parameters listed. The detailed equations which relate the indicated variables to each particular parameter listed are shown in Appendix A.

Table III shows the value of the system parameters listed in Table II using the equations of Appendix A.

The data on Table III allows the manager to make a better judgment than that on Table I, however, there is still no direct basis for comparing the alternatives.

The manager may further reduce the variables which he must consider by relating all of the parameters which contribute to the effectiveness (military worth) of the system into one value and those parameters which contribute to the cost, or disadvantages, of the system into another value. Appendix A assumes the relationships are as follows and computes the values indicated on Table IV.

E (Effectiveness) = Payload X Cruise Vel. X Op. Readiness X Prob. of Mission Success X No. Aircraft

C (Life Cycle Cost) = R&D Costs + Investment Costs + Total Operation & Support Costs

The values of Table IV, when plotted on a graph of effectiveness versus cost, are shown on Figure 1.

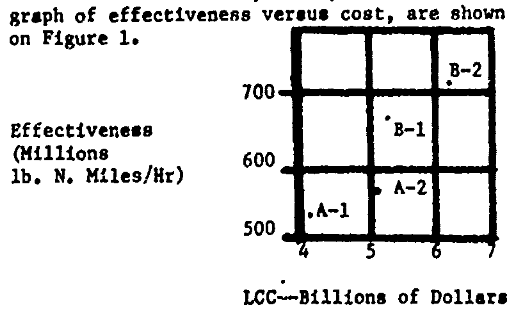

Figure 1

From Figure 1, it is obvious that Configuration A-2 is the worst choice of the alternatives available. However, the best choice from Configurations A-1, B-1 or B-2 is not obvious.

In the real world, judgment can be applied in selecting one of the following:

Lowest cost	Configuration A-1
Greatest effectiveness	Configuration B-2
Lowest risk	Configuration A-1

A more "scientific" ranking of the alternatives may be achieved by assigning a numerical value to the relationships between the effectiveness of a system and its military worth to the operator expressed in dollars (function f_m in Appendix A).

By assigning a value to f_m of $12/lb.-n.mi./hr. the net military gain resulting from the acquisition of each of the alternatives as listed below may be calculated using the equation:

G (Net Military Gain) = 12 X E (Effectiveness) - C (Life Cycle Cost)

Net Military Gain	Alternative
$2.830 B	B-1
2.470 B	B-2
2.371 B	A-1
1.729 B	A-2

Thus, the acquisition manager, by the above procedure, may rationally select Configuration B-1 as the best weapon system from the available combinations of airframe and propulsion subsystems.

From the above example and the supporting equations of Appendix A the discussion that follows outlines some general principles that were used to define and structure data in a form which allows the decision maker to make a rational decision. It is suggested that these principles may have broad application to decision making, in general.

The overall principle is that management should strive to deal with data that are objective, quantitative and measurable. This is the essence of science as compared to art. Without belaboring the merits of being "scientific," scientific methods are more effectively communicated, taught and verified. Erroneous postulates can be independently measured and corrected and the methods thereby improved with time.

First--what is the nature and content of the decision to be made? In this example, the specific decision is the selection of the best combination of subsystems from the options available.

Second--what is the criterion by which the decision maker should rank the alternatives available? There are several general characteristics of the required preference criterion which are believed to be of primary significance.

. The criterion should measure the degree to which each alternative contributes to the higher level need which originates from <u>outside</u> the organization. In this case, the operating command (an "outside" organization) has a need for an expanded logistic support capability.

. The preference criterion should be a single-valued measure of the contribution of each alternative of the higher level need. It is suggested that every decision maker, in the final analysis, must use a criterion which provides a common single-valued basis for directly comparing the alternatives. Otherwise, he cannot rationally rank one alternative relative to the other. In this example it was assumed that the single-valued criterion, net military gain, measured the contribution each alternative made to satisfying the Navy's need for additional logistic support.

. Ideally, the preference criterion should relate all of the advantages of each alternative to all of the disadvantages of the same alternative. In this example, all of the advantages are combined in the term "Effectiveness" and all of the disadvantages in the term "Life Cycle Cost." The relation between Net Military Gain (G), Effectiveness (E), and Life Cycle Cost (C) were given by the equation:

$$G = 12E - C$$

Third--what data must be collected in order to rank the alternatives? It is believed to be self evident that the data listed in Table I had to be derived by beginning with the assumed single valued criterion (Net Military Gain) and then deriving the measurable quantitative variables which were necessary to determine the value of the Net Military Gain offered by each alternative available. This was the procedure by which the variables listed in Table I were derived in Appendix A. The general conclusion is that the <u>decision maker should develop the data needed from his subordinates</u> rather than vice versa. Otherwise, the data are likely to be redundant and/or incomplete.

In this example, after the acquisition manager has selected Alternative B-1, it is appropriate that the variables listed for Airframe B and Propulsion System 1 be established as objectives - (along with the schedule and other constraints) for the airframe and propulsion system contractor, respectively. Single-valued objectives for the best subsystem to match each of the two alternative

subsystems may be developed from the variables listed on Table I. This development is beyond the scope of this paper.

(In this paper it is suggested that the term "need" used by the strategic operator, "objective" or "goal" used by the general manager, "requirement" used by the engineering manager, or "purpose" used by the behavioralist are different terms which generally have the same meaning. Other than in the case of the Mission Element Need Statement, the term "Objective" is used in this paper.)

It would appear to be self-evident that, when the weapon system manager is assigned the responsibility for a MENS, he should also be provided with the resources necessary to implement the program required to satisfy the needs defined therein. Also, when the weapon system manager allocates objectives for the airframe contractor and propulsion system contractor (in the example), it would also appear self-evident that he must allocate the resources provided to each contractor in order for the objectives defined for each subsystem to be satisfied.

Although the above case assumes a precise measurable objective for the system and the subsystems, in the real world the problems are many times more complicated. All knowledge never resides in a single individual or organization. It is considered important both from the viewpoint of getting the most appropriate, precise and measurable objectives and also getting the cooperation of all participants that the objectives (and constraints) should be negotiated between superior and subordinates; not unilaterally directed from on high.

It is also suggested here that the two alternative airframes and the two alternative propulsion systems, each with the associated resources required for implementation of the alternative, represent logical "decision packages" for management to consider in effecting Zero Based Budgeting.

OMB BULLETIN A-109

The above example illustrates the nature and content of the decisions which must be made in only one life cycle phase (pre DSARC I) and in the acquisition process of a major system at only one work breakdown structure level.

The discussion that follows expands to consider the acquisition process over the life cycle of a weapon system as defined by OMB Bulletin A-109 and DOD Directive 5000.1. Another concept is the proposition that all acquisitions proceed through five relatively distinct life cycle phases, and that each phase generates information in the form of a contract between the relatively distinct type of manager who must manage each successive phase. These phases, including the relationship to the DSARC decisions as defined in Department of Defense Directive 5000.1, the type of manager involved and (in the case of major weapon systems), the primary document or "contract" generated as the result of each phase, are listed below:

LIFE CYCLE PHASE	TYPE MANAGER INVOLVED	PRIMARY DOCUMENT PRODUCED
. Identification of a need (pre DSARC 0)	. Strategic Operators	. Mission Element Element Need Statement
. Definition (and validation) of program plan (pre DSARC I)	. Weapon System Preliminary Design Manager	. Weapon System Development Contract (including the System Performance Specifications)
. Design (and development) (Pre DSARC II)	. Weapon Systems Design Manager	. Weapon System Production Contract (including the System Design Data Package)
. Production (pre DSARC III	Weapon System Production Manager	Actual Systems with Operating and Support Instructions (The actual manufacture of systems is outside the definition of managers as discussed in this paper)
. Operation (post DSARC III)	. Operating Command	

As the acquisition process proceeds through these life cycle phases, the decisions made during each phase successively narrow the choices available at each successive phase.

Also, as the process proceeds, the decisions made at the higher levels of the work breakdown structure of a weapon system successively narrow the choices available at each lower level of the work breakdown structure. (In the example, after airframe B and propulsion

system 1 are chosen, effort at the lower work breakdown structure levels is limited to these subsystems.)

A description of an acquisition decision model which divides the process by life cycle phases and work breakdown structure level is outlined in detail in a forthcoming paper in the "Defense Systems Management Review" and will not be discussed in any detail here. Briefly, however, the decision model describes a complex process in which gross requirements and total resources are successively broken down into a more detailed definition of the weapon system's elements, with each element being allocated a smaller share of the total available resources. Throughout the process, needs and available resources (which flow from the managers responsible for the higher work breakdown structure levels and earlier life cycle phases) must be matched with available alternatives and required resources (which flow from the managers responsible for the lower work breakdown structure levels and later life cycle phases of the weapon systems).

During this complex process, the Weapon System Manager, by reviewing the results of analyses and tests, by continuous monitoring of the process and by making the program changes as indicated, strives to reduce the risk (as numerically listed on Table I in the example) associated with achieving all performance objectives established at multiple management levels.

MANAGEMENT BY OBJECTIVES (MBO)

It is the writer's understanding that the following are the key elements of MBO:

. Use of quantified measurable objectives at all levels of the organization.

. Negotiation of objectives between superior and subordinate.

. Periodic review of the subordinate's progress relative to objectives.

. Rewards to the subordinate related to the degree to which he achieved the assigned objective.

It is also the writer's understanding that MBO has met with mixed success. In the writer's experience in this regard, MBO has been weak because there has been little guidance on how to select and structure objectives which are most significant to the operational success of the organization. It is believed that MBO can be improved by developing an integrated hierarchical structure of objectives from the top down generally following the procedure used in Appendix A. Furthermore, managers should strive to develop single-valued objectives which relate all of the advantages of the available alternatives to all of the disadvantages.

ZERO BASED BUDGETING (ZBB)

Fundamental to the ZBB process is the development of decision packages. Each budget package which describes an objective which is expected to be achieved for the expenditure of the resources is indicated in the package. These packages are then ranked and the "best" combination aggregated at successively higher levels.

The discussion of this paper suggests that the structuring of objectives with the associated required resources meets the requirements for decision packages required by ZBB. For the reasons discussed herein, it is believed to be essential that the ZBB decision packages and the budget structure which support ZBB must be developed by management from the top down if the decision packages are to be compared on any common basis and are to be rationally aggregated from the bottom up.

The above discussion has centered essentially upon the mechanics of the acquisition process. Early in the paper the assumption is made that "it is the objective of each manager, at all levels of the organization, to make those decisions which will result in providing the operating command with the "best" weapon system..." One of the primary challenges facing management is the motivation of personnel at all levels to pursue individual work objectives consistent with the overall objectives of the organization. MBO deals with the issue by instituting the process of requiring superiors to negotiate objectives with subordinates. The superior must track objectives with rigor in order to emphasize their importance to subordinates. The reward structure (financial and otherwise) of the organization should reward subordinates in relation to the degree to which assigned objectives are satisfied. This is often difficult under the Civil Service System.

Lastly the development of objectives by a process similar to that illustrated here, lends itself to extensive use of computers. Managers should provide the judgmental inputs and computers can then provide the mathematical calculations.

SUMMARY

The following paragraphs list each of the principles or concepts emphasized in this paper and briefly discuss the relationship of each to the management disciplines of OMB Bulletin A-109, Zero Based Budgeting and/or Management By Objectives.

. The management of acquisition is a hierarchical decision process which generates information. This broad principle is applicable to all of the three

management disciplines.

. The primary decisions made by managers in the acquisition process are those required to negotiate the objectives for the subsystems with subordinate managers which will satisfy the higher level system need (objective) which has been negotiated with his superior from outside the organization (the procedure by which these objectives are achieved are secondary). These hierarchies of objectives and subobjectives are considered to be the essential links between weapon system design objectives and subsystem design objectives at each phase of the acquisition process defined by OMB Bulletin A-109.

. The acquisition process proceeds through relatively distinct life cycle phases with formal documents (or contracts) generated during each phase. This concept describes the process consistent with OMB Bulletin A-109/DOD Directive 5000.1.

. Ideally, all objectives should be quantitative and measurable. Also ideally, these objectives should serve as a single-valued criterion by which the decision maker ranks the alternatives available. In addition, the criterion should relate all of the advantages of each available alternative to all of the disadvantages. These principles are equally applicable to MBO and the objectives of decision packages developed under ZBB.

. The resources obtained from outside the organization must match the higher level system need assigned from outside and must be allocated consistent with the objectives for subsystem objectives which are negotiated with subordinates. This principle is consistent with MBO and the decision packages required by ZBB.

. An integrated and quantitative hierarchical structure of objectives must be developed from the top down. It is suggested that this principle must apply both to the hierarchical structure of objectives which is required by MBO and the hierarchical budget structure required by ZBB if these processes are to be rational and effective.

. Objectives should be negotiated between superiors and subordinates and each manager's reward should be related to the degree to which he achieves the assigned objective.

CONCLUSIONS

Managing the acquisition of weapon systems in the future will be an extremely challenging task for the individual manager and for our nation.

There are new management disciplines available as well as the technology of greatly expanded computers and automated management information systems which can promote improvements in the acquisition process.

The application of more precise management disciplines and advanced information systems is limited by the culture (in particular, that of the Government sector) of our society. Managers at all levels are challenged to build a reward structure which will align the objectives of the individuals with those of the organizations in which they work. Changes in reward systems which will motivate all individuals to move to emphasize the following are believed necessary:

. Top management concentration on "top down" developed objectives and constraints rather than detailed procedures.

. Management concern with no more detail than is necessary to manage the objectives assigned at each appropriate level (much less micro-management).

. Resources allocated in direct support of objectives at all levels with the appropriate supporting accounting structure.

. Rigorous tracking of accomplishment and expenditures against objectives.

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TABLE I - CHARACTERISTICS OF SUBSYSTEMS

	AIRFRAME A			AIRFRAME B		
	Est. Value	Est. Risk	Expected Value	Est. Value	Est. Risk	Expected Value
Ave. Cruise Velocity (knots)	500	0	500	550	.01	544.5
Effective Lift-Drag Ratio (Dimensionless)	15	0	15	16	.01	15.84
Airframe Weight (lbs.)	15,000	0	15,000	14,000	.03	14,432
Airframe Failure Rate (Failure/Flt Hr)	1.0	.03	1.03	0.7	.10	0.777
Airframe Mean Time to Repair (Hrs)	10.0	.02	10.2	8.0	.04	8.33
Airframe Overhaul Interval (Hrs)	500	.02	490	600	.08	552
Ave. Mission Time (Hrs)	6	0	6	5.45	.02	5.56
Airframe R&D Costs ($ Millions)	0	0	0	300	.10	333
Airframe Investment Costs ($ Millions)	500	.05	526	700	.08	760
Airframe Oper & Sup Costs ($ Millions)	2,350	.08	2,554	2,500	.12	2,841
Airframe Initial ILS Costs ($ Mill.)	0	0	0	350	.08	380

	PROPULSION SYSTEM 1			PROPULSION SYSTEM 2		
	Est. Value	Est. Risk	Expected Value	Est. Value	Est. Risk	Expected Value
Engine Efficiency (Dimensionless)	0.28	0	.28	0.32	.05	0.306
Engine Weight (lbs.)	2,800	0	2,800	2.200	.02	2,244
Engine Failure Rate (Failure/Flt Hr)	0.2	.02	0.204	0.15	.08	0.163
Engine Mean Time to Repair (Hrs)	5.0	.01	5.05	8.0	.03	8.247
Engine Overhaul Interval (Hrs)	500	.03	485	1,000	.10	900
Engine R&D Costs ($ Millions)	0	0	0	250	.10	278
Engine Investment Costs ($ Millions)	200	.04	208	350	.06	372
Engine Oper & Sup Costs ($ Millions)	800	.06	851	900	.10	1,000
Engine Initial ILS Costs ($ Millions)	0	0	0	280	.06	298

TABLE II - VARIABLES USED TO CALCULATE SYSTEM PARAMETERS

SYSTEM PARAMETERS	VARIABLES (FROM TABLE I)
Payload	Engine efficiency Effective lift-drag ratio Airframe weight Engine weight
Average cruise velocity	(Assumed)
Operational Readiness	Airframe failure rate Engine failure rate Airframe mean time to repair Engine mean time to repair Airframe overhaul interval Engine overhaul interval
Probability of mission success	Airframe failure rate Engine failure rate Average mission time
Research and Development Costs	Airframe R&D costs Engine R&D costs
Investment costs	Airframe investment costs Engine investment costs
Total operation and support costs	Initial airframe ILS costs Initial engine ILS costs Airframe operation and support costs Engine operation and support costs

TABLE III - CHARACTERISTICS OF SUBSYSTEM COMBINATIONS

	EXPECTED VALUES						
SUBSYSTEM COMBINATION	PAYLOAD (LBS)	AVE. CRUISE VELOCITY (KNOTS)	OPERATIONAL READINESS (PERCENT)	PROB. OF MISSION SUCCESS (PERCENT)	R&D COSTS ($M)	INVEST. COSTS ($M)	TOTAL OPER. & SUPT. COSTS ($M)
A-1	17,100	500.0	69.3	90.5	0	734	3,404
A-2	17,653	500.0	68.4	87.5	278	898	3,852
B-1	18,420	544.5	73.6	92.6	333	968	4,072
B-2	18,882	544.5	74.6	89.5	611	1,132	4,519

TABLE IV - EFFECTIVENESS AND COST OF SUBSYSTEM COMBINATIONS

SUBSYSTEM COMBINATIONS	EFFECTIVENESS (lb-N.Miles/Hr)	LIFE CYCLE COST ($M)
A-1	542,430,500	4,138
A-2	563,098,700	5,028
B-1	683,560,200	5,373
B-2	727,674,300	6,262

APPENDIX A

$G = M - C$

Where:

G = Net Military Gain ($)

M = Military Worth ($)

C = Life Cycle Cost ($)

$M = f_m E$

Where:

f_m = A function which relates military effectiveness to military worth ($/lb.-n.mile/hr.)

E = Military effectiveness (lb.-n.mile/hr.)

$E = W_p x \overline{V}_c OR x S_o x N_a$

Where:

W_p = Payload (lbs.)

$\overline{V}_c$ = Average cruise velocity (knots)

OR = Operational readiness (dimensionless)

S_o = Probability of mission success (dimensionless)

N_a = Number of aircraft (dimensionless)

$$W_p = \frac{W_g}{2.718^{\left(\frac{R}{he\,L/D}\right)}} - W_a - W_e$$

Where:

W_g = Aircraft takeoff gross weight (50,000 lbs. used for this example)

R = Aircraft range (3,600 n. miles used in this example, which is greater than the requirement of 3 000 n.miles to allow for warm up cl' , reserve, etc.)

h = Energy content of the fuel (2,400 n. mile - lbs/lb. used for this example)

e = Engine efficiency (dimensionless)

L/D = Effective aircraft lift-drag ratio (dimensionless)

W_a = Airframe weight (lbs.)

W_e = Engine weight (lbs.)

$$OR = 1 - F_a \left(f_{sa} + f_{wa} + \frac{f_{3a} x MTTR_a x FH}{T}\right)$$

$$-F_e \left(f_{se} + f_{we} + \frac{f_{3e} x MTTR_e x FH x N_e}{T}\right)$$

$$- f_{oa} \left(\frac{FH}{t_{oa}}\right) - f_{oe} \left(\frac{FH}{t_{oe}}\right)$$

Where:

Fa = Airframe failure rate (failures/Flight hour)

f_{sa} = A function which relates the not operationally ready rate due to supply (NORSa) of the airframe to the airframe failure rate.

$\left(\frac{NORSa}{Fa}\right)$ (0.20 used for this example)

f_{wa} = A function which relates the airframe awaiting maintenance rate (AWSa) to the airframe failure rate $\left(\frac{AWSa}{Fa}\right)$
(0.005 used for this example)

f_{3a} = A function which relates the airframe downing event rate to the airframe failure rate $\left(\frac{DEa}{FHxFa}\right)$
(0.10 used for this example)

$MTTR_a$ = Meantime to repair the airframe (hours)

T = Total aircraft lifetime (hours) (175,200 used in this example)

f_{oa} = A function which relates the not operationally ready rate due to scheduled maintenance of the airframe to the number of scheduled overhauls $\left(\frac{NORMS(P)a}{no\ overhauls}\right)$
(0.001 used for this example)

t_{oa} = Scheduled overhaul interval for the airframe (hours)

N_e = Number of engines per airframe (two for this example)

FH = Aircraft lifetime flight hours (7,200 for this example)

F_e = Engine failure rate (failures/flight hour)

f_{se} = A function which relates the not operationally ready rate due to supply (NORSe) of the engine to the engine failure rate $\left(\frac{NORSe}{F_e}\right)$
(0.18 used for this example)

f_{we} = A function which relates the engine awaiting maintenance rate (AWSe) to the engine failure rate $(\frac{AWSe}{F_e})$

(0.005 used for this example)

f_{3e} A function which relates the engine downing event rate to the engine failure rate $(\frac{DEe}{FH \times F_e})$

(0.15 used for this example)

f_{oe} = A function which relates the not operationally ready rate due to scheduled maintenance of the engine to the number of scheduled overhauls $(\frac{NORMS(P)e}{No\ overhauls})$

(0.001 used for this example)

MTTRe = Mean time to repair the engine (hours)

$$S_o = 1 - f_{2a} F_{at} - f_{2e} F_{et} - \frac{f_{1a} F_{a}t}{f_{1a} F_{a}t + 1} - \frac{f_{1e} F_{e}t\, N_e}{f_{1e} F_{e}t\, N_e + 1}$$

Where:

f_{1a} = A function which relates the airframe caused deck abort rate to the airframe failure rate $(\frac{DAa}{F_a \times FH})$

(0.01 used for this example)

f_{2a} = A function which relates the engine caused flight abort rate to the engine failure rate $(\frac{FAa}{F_a \times FH})$

(0.002 used for this example

f_{1e} = A function which relates the engine caused deck abort rate to the engine failure rate $(\frac{DAe}{Fe \times FH})$

(0.008 used for this example)

f_{2a} = A function which relates the engine caused flight abort rate to the engine failure rate $(\frac{FAe}{F_e \times FH})$

(0.002 used for this example)

t = Average mission time (hours)

$$C = C_{Ra} + C_{Ia} + C_{Oa} + C_{La} + C_{Re} + C_{Ie} + C_{Oe} + C_{Le}$$

Where:

C_{Ra} = Total airframe peculiar research and development costs ($)

C_{Ia} = Total airframe investment costs for all production units ($)

C_{Oa} - Total airframe operation and support costs ($)

C_{La} = Total initial airframe logistic procurement and support costs ($)

C_{Re} = Total engine peculiar research and development costs ($)

C_{Ie} = Total engine investment costs for all production units (including complete spare engines) ($)

C_{Oe} = Total engine operation and support costs ($)

C_{Le} = Total initial engine logistic procurement and support costs ($)

The above example assumes that each aircraft system can use either propulsion system and still achieve the performance quoted for the airframe.

A NEW CONTROL SYSTEM FOR ARMY PROCUREMENT APPROPRIATIONS: LOOKING FORWARD IN FINANCIAL MANAGEMENT

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Washington, D.C.

INTRODUCTION

Changing an entrenched accounting and financial management system that handles over $20 billion annually called for some hard questions to be asked. Coming up with the answers was an even greater challenge.

Over the past several years, financial management requirements for the Army have undergone major changes, especially in the area of procurement appropriations. Unfortunately, these changes led to major problems for the existing accounting systems, fund control procedures, and management information reports and procedures.

The accounting systems in 1970 were designed to manage a single procurement appropriation for the Army. A comparatively small amount of reimbursable accounting was required for other customers, such as the Air Force, Marine Corps, and Foreign Military Sales. Then in mid-fiscal year 1971, Congress changed the accounting structure from one appropriation to five separate procurement appropriations. This was done primarily to gain better control and visibility over the procurement program.

But there were major ramifications. The new appropriations could only be used for obligation of the approved funds for three years and for expenditures for two additional years. Each year five more appropriations were approved by Congress. Attempts to adapt the existing Army accounting system to this drastically changed environment proved inadequate. In 1975, at the end of the obligation and expenditure life of the 1971 appropriations, a series of violations of law (Revised Statute 3679 - Anti-Deficiency Act) was discovered. Overallocation of funds, lack of adequate accounting control, overobligations, and unreconcilable records were identified.

The expansion of Foreign Military Sales during this same period (1971 through 1975) further complicated the management problem. The FMS program grew to a magnitude almost equal to the congressionally approved program for the Army's needs. The procurement appropriation accounting system could neither effectively manage the volume, nor provide the essential FMS management data such as contract accounting and case control. An attempt was made to rely on the logistics system to control FMS financial resources, but it lacked adequate controls and accounting discipline.

As a result of the accounting system's weaknesses, meaningful management information depicting the growth of the problem could not be produced. This void was directly compounded by the basic inadequacies in the financial systems and the fact that the Army-level management information system had not been fully implemented.

Manually updated ledgers, used to record and control program and fund authorization, were until recently the prime management tool. Although fund authorization data were often fed into partially automated accounting ledger systems, there were inadequate controls, lack of effective reconciliations, and inadequate and outdated management reports. Balances for the same appropriation status differed between Department of Army, major Army commands, and the Army Finance and Accounting Center. This resulted in a continual dispute over the accuracy and reliability of fund data.

When the full magnitude of the violations was recognized in 1975, investigations and special studies identified many specific problems. The Army undertook an extensive corrective action program to prevent recurrence, but the basic financial management system was not changed. Additional violations merely highlighted the necessity for a basic reevaluation of system needs. The decision in October 1976 to design and implement a new system that could help solve the basic problems and gain formal General Accounting Office approval within one year obviously represented a major challenge.

Twenty-five separate procurement appropriations comprising thousands of procurement items for support of the Army must be managed on a detailed basis. In addition, the Foreign Military Sales program must be managed as a part of each appropriation. In many cases, the FMS program was actually greater than the Army's program in total value and quantity of material. The result was the requirement to manage 50 separate programs with a total value exceeding $20 billion.

The existing financial systems provided

neither adequate control of FMS cases nor adequate management information to establish financial control over the appropriations. Despite an extensive effort to improve the existing automated and manual procedures and records, basic weaknesses remained that were beyond the capability of the old systems to correct; for example, positive controls did not exist to prevent release or utilization of more authority than was authorized. The fact that major program and fund managers had different figures after this significant effort to improve management and control further indicated a need for reassessment. It was concluded that the needs of the Army were to:

- Establish essential financial control over appropriations to prevent violations of law.

- Maintain the current appropriation status.

- Establish one set of official records useable by all.

- Improve the timeliness and accuracy of financial information.

- Expedite the provision of resources to the levels executing the program.

- Simplify the overall management process.

- Implement a responsive system.

These specific objectives were crystallized via a 90-day, Executive-level management study directed by the Secretary of the Army and conducted by a Blue Ribbon civilian advisory group known as the Financial Management Advisory Committee. Their report was accepted by the Secretary of the Army in June 1976, and a high-level implementation steering group was formed immediately. Chaired by the Under Secretary of the Army, this group was chartered to ensure that strong, positive actions were taken. The implementation of a new program and fund control system for Department of the Army headquarters was a specific objective established by the steering group.

Rapid implementation of the new system necessitated a critical-path management process. Planning, design, coordination, and implementation were conducted simultaneously, with the basic objectives as the guide. However, detailed planning and documentation could not be slighted since the U.S. Army Audit Agency was to be requested to conduct a real-time audit of the effort, and the designs were to be formally submitted to the General Accounting Office for system approval during the design and implementation process.

A WORKABLE CONCEPT

Brainstorming by staff and systems personnel led to the realization that a real-time data base management system was required. This would involve tying the major Army Staff elements involved in the management process together with major Army commands, subordinate commands, and the central accounting centers. A preliminary design concept, stated in a management requirements paper, was then developed. It specifically defined what program and fund actions would be managed; the controls to be imposed by the system; and that all inputs and most outputs would be managed through the communication terminals operated by each system user. From its inception, the system was to become a management control process more so than a management information system.

The fact that the Army did not have the computer capability to support such a state-of-the-art systemization led to the decision to implement the system using contractor support until in-house capabilities were available. Contractor support was used to refine the detailed design of the system, to perform the necessary programming, and to support the operational system when implemented. The contractor was not to determine what was needed, but was to accomplish technical support and programming and act as the computer expert upon system implementation.

The overall system initiative for the procurement appropriations involves the three major phases in Figure 1.

Figure 1. The Three Phases of the System Initiative

Phase I: Program and fund control at Department of the Army headquarters and to major Army commands.

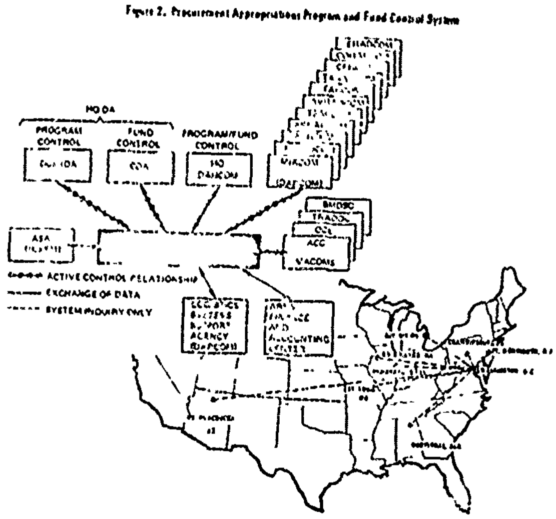
Phase II: Extension of the program and fund management system as a management tool within major Army commands and to the executing levels.

Phase III: Financial control of the Army Customer Order Program.

Because the system would function as a management control tool at various levels, each organization's requirements were separately addressed and integrated to meet the basic objectives. Ensuring significant managerial benefits at each system level added to the complexity, since the system was not to become solely a management information source for Department of the Army. The organizations involved and their locations are reflected in Figure 2, while the operating concept is reflected in

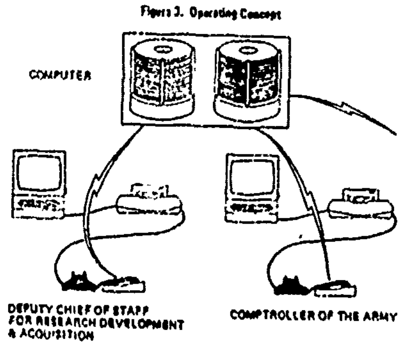
Figure 3. The number of involved organizations and their geographic diversity indicate the magnitude of the coordination and planning tasks.

Figure 2. Procurement Appropriation Program and Fund Control System



The system integrates the entire program and fund release process, from the congressional authorization of procurement appropriation items, through Department of Defense program release actions, through Department of Army releases, through the major command actions, and to the executing levels. All involved have total real-time visibility of actions affecting them. In terms of processing times, high-priority items can be totally released to an executing agency in less than an hour; under the previous system, it took more than a week.

Figure 3. Operating Concept



The Phase I system was fully implemented on May 20, 1977. It was designated the official Army record, and all fund and program changes are being processed through the system. This virtually eliminated the need for reconciliations among manual records and reduced the necessity for generating numerous and differing status reports at each level. In addition, it eliminated the need for extensive telephonic coordination to determine the status of actions taken at different organizational levels, since each user can obtain this information at his terminal. An immediate answer is provided.

Since the system functions as a part of the total Army financial system, a system transaction automatically generates taped interfaces to other financial systems (at the Logistics System Support Agency and the Army Finance and Accounting Center) through AUTODIN. This effects major savings in terms of document processing time and review, elimination of reference ledger systems, keypunching, and verification of data inputs.

Although savings and significant improvements have been and will be realized when full implementation of all phases is complete, the basic justification for the system was always to provide improved financial control and accurate information for analysts and decision makers. Many analysts previously involved in routine bookkeeping functions are now able to devote their time to analysis instead. Phases II and III are presently scheduled to be tested and implemented in March 1978. Due to their scope, their implementation will be phased to allow earlier use of high-priority modules as they are tested and integrated into the system.

"On-line" refers to the fact that system users (budget and financial analysts) have direct access to the central processing unit at all times, either for data input or file inquiry. To ensure security and control, the system limits access by controlling which users are allowed to perform certain functions, and by requiring a combination of password and user access identifiers. This is in contrast to a "batch" system method of periodic bulk processing in which similar financial transactions are stock-piled in punch card form to be run through a computer as a group either daily, weekly, or monthly, as is done in all other Army-level financial systems.

The main advantages of direct and continued access to the computer is that it permits immediate updating of files. Thus, the system can compare desired input to the current status of a financial item. If the transaction is acceptable, it is approved. If an action could violate internal system control, the transaction is disapproved and the requester is notified immediately. In other words, the Army's procurement appropriations program, fund authorization, and allocation files should always be current, enabling management personnel to obtain up-to-date information by simply pushing a few keys on the system communication terminal.

A REPRESENTATIVE ACTION

When the program manager decides to release an item to a major command so that it can, for instance, initiate the procurement of tanks, the authorized analyst enters the system and requests release of the tanks. The system verifies that the congressional authorization has been entered for the tanks. It verifies that the Defense Department has released the program and that unallocated funds are available. It verifies that no congressional limitations exist, and it performs many other checks. These automatic controls are the heart of the system and differentiate it from batch-related management information systems.

If all controls are met, the program release request is passed through the system to the Comptroller of the Army's office, where checks are performed and funds are released by entering the approval into the system. After approval, files are automatically updated, the release is immediately provided to the major commands, and the action is posted to a tape file. The file is passed through AUTODIN to the Army Finance and Accounting Center and the Logistics System Support Agency, which maintain the overall accounting systems and presently accumulate the financial data with regard to executing the approved items (such as obligations and disbursements). These interfaces feed the systems that produce the Army's official financial reports.

Upon receipt of the release (after Phase II has been implemented), the major command will effect a similar release process through the communication terminal at their headquarters. The approved action is transmitted to the executing agency's communication terminal; they then have the authority to initiate obligation and procurement of the item. Financial files will be updated through AUTODIN tape, and any system user can check the exact status of the action while it is being processed.

IMPLEMENTATION UNIQUE

Many organizations were involved in implementing the system; consequently, a unique management process was required. The project officer worked simultaneously for the program director in developing the program management process; the Comptroller of the Army in establishing the financial management policy and procedures; and major commanders in executing agency policy and procedures. Also, such factors as management of the contract process, training, implementation planning, system documentation, system maintenance, acceptance testing, parallel testing, and preparation of GAO submission required coordination at every level.

Initial development was accomplished under the Director of Army Budget. When the Army headquarters system was implemented in May 1977, the basic system direction was passed to the Director of Finance and Accounting, since the system became an operating accounting system.

The Phase I system has proven to be highly reliable and easy to use. This useability directly resulted from a careful evaluation of user requirements and from ensuring that the system would simplify the management process at each user level. This required that attention be directed not only to solving the major long-range problems, but also to the highly specific needs of each using organization.

Changing policy as well as the method of operation required a special management effort. Many managers have been victimized by their own well-intended modernization efforts, only to be overwhelmed by expensive electronic gadgetry and complex computer outputs. This danger was an ever-present concern. The first phase, although rushed to successful completion, pointed out the necessity for a carefully staged expansion of the system to make certain that the highly sophisticated automatic data processing system would fully accomplish all of its objectives when completely implemented. The need was to concentrate on <u>people</u> rather than computers or systems, introducing them to various degrees of modernization one step at a time.

RESULTS AND THEIR EFFECT

Simultaneous design, coordination, development, and implementation was and remains a formidable task. The need for continuous planning was required just to keep up with changes and new requirements. The faster the implementation, the greater the potential for a critical oversight; but the analysts, accountants, and systems people are adapting well to the rapid rate of change, and have made a success of the first phase of the implementation effort.

Ernst and Ernst, certified public accountants and management consultants, evaluated the Phase I system. They recommended expansion of the approach to other Army appropriations, as well as rapid implementation of defined follow-on phases. This appraisal was corroborated by the U.S. Army Audit Agency evaluation of the basic system, which concluded that the system possesses the integrity needed to preclude the Department of the Army-level problems previously experienced in the Army's procurement appropriations.

The lessons which have been learned and are being evaluated for wider impact are as follows:

- The Army should pattern its new financial system to match its needs rather than be a slave to continual modification of existing, outdated card-based systems.

- Card-based systems are not capable of effecting internal system control.

- Any major changes to existing systems should be carefully evaluated prior to expending resources for modifications that might result in limited benefits.

- Computer functions must be distributed away from central sites and out from under the direct control of ADP centers.

- Executive-level support throughout the development of a new system is essential to maintaining the initiative and reinforcing the organizational commitment to change.

- Continual communication of progress, problems, and actions under way is essential to ensure user understanding and involvement in the system development, implementation, and use. Systems are developed with people, not for them.

- System tuning after initial implementation can be as critical to long-range success as any step in the process.

- Contractor support to implement a system can be an excellent tool if strong performance objectives are established and pursued.

This system approach is the trend the Army is taking for its financial systems development in view of new technology and system capabilities. Financial managers must look to the future, learn to manage the development of new systems, and accept the challenges that will result.

LIFE CYCLE COSTING

HOW FAR IS THE GOVERNMENT WILLING TO GO TOWARD REDUCING LIFE CYCLE COST OF MILITARY WEAPON SYSTEMS?

J. F. Drake, Corporate Director, Advanced Program Plans, Hughes Aircraft Company

I. INTRODUCTION

The Department of Defense has new opportunities related to the acquisition of avionics equipment and systems. Solid state devices, digital micro-electronic circuitry, cryogenic devices, fiber optics and other technological achievements available to industry have dramatically improved the reliability of avionics systems and promise even more significant advances in their near term application.

As a result, mission reliability is significantly improved. Current weapons and systems can withstand the packaging, shipping, handling, loading, storage and captive flight environment and still deliver on target using conventional operating crews. Further technological advances can only improve the existing high mission reliability.

These same improvements reduce weight, volume and power requirements and permit operation with reduced and/or no requirement for liquid coolants or hydraulic fluids. These factors combine with reliability to reduce the malfunction rates. Therefore, maintenance is reduced, and it is the driving function which establishes the peoples and materials necessary to sustain mission success.

The combination of improved reliability and decreased maintenance permits concepts of operation that offer maximum readiness at minimum operating and support (O&S) costs. Thus, beneficial changes in all phases of the acquisition process for avionics equipment should be achievable, but not without change to existing government policy and procedures. The changes will require doing a better job of planning; breaking with tradition; and halting the growth of and/or reducing the ever increasing government payroll.

The question really is "how far is the government willing to go in reducing the life cycle costs of military weapon systems?" This is a critical question if we are to maintain a strong defense posture within the financial limitations imposed by the President and Congress. If the answer is to maximize our defense capability within the dollars available, then the theme of this conference, "Working Tomorrow's Procurement and Acquisition System Today," is appropriate. Time will be required for the changes that I propose. Some are within the authority of various levels of DOD but lack a consensus. Others need Congressional approval. Some may have substantial political implications. All will add credibility to the advertised DOD policy.

II. DEVELOPMENT

1. OMB Circular A-109 — the Key Is Flexibility

OMB Circular A-109 establishes the policy to be followed by executive agencies in the acquisition of major systems. It is the current end point in the evolution of weapons system acquisition. It is a process based on mission need that brings cost and risk into focus through a series of high visibility reviews conducted at the completion of scheduled periods of activity. On the positive side, the process provides a method to achieve performance goals, reduce costs and avoid risk. On the negative side, it may increase cost by increasing the length of the acquisition cycle, adding more people to the decision making process, and increasing the tendency to over control.

With flexibility properly utilized, the acquisition process can improve our defense posture and provide a basis for getting more for our dollar. To do so requires that we again evaluate the overall process to highlight recommendations that could result in cost savings and increased readiness — or at least no readiness degradation. Many of these have been emphasized before and while some have already been implemented, their importance to the overall process justifies further discussion.

2. A Good Contract Requires Extensive Forthright Communications

The key to a successful development program is a specification, work statement, and set of contractual terms and conditions established through extensive face-to-face dialogue between the contractor and the Service Program Office. Only through such dialogue can obsolete MIL specifications and unnecessary requirements be avoided, the most cost effective technology appropriate to each subsystem be selected, a full and mutual understanding of the critical requirements be established, and the risks to be evaluated.

During the late '60s and early '70s, the Contract Definition Phase (CDP) was intended to serve this purpose. In many cases it was not successful, since the dialogue was limited or restricted to questions and answers versus forthright debate.

An example of a successful CDP was the one conducted on the Maverick program at the AF

Aeronautical Systems Division. It was successful primarily because the specification negotiations were carried out in detail over a period of about 11 months, and contract negotiations, over 18 months. I participated as the Hughes program manager and I can assure you it was an enervating experience. Nevertheless, both parties fully understood the contract at the conclusion of the CDP, and it was a tough but fair contract. It also resulted in the only successful major total package procurement program to our knowledge.

In contrast, RFPs now reflect a 30 day response time. The contractors generally respond with only minor suggestions, for they find it advantageous to do so from a competitive point of view (i.e., don't rock the boat). The need to be responsive to customer stated requirements is always present and becomes critical when customer communication is lacking or prohibited.

Improved communications suggest that extensive face-to-face dialogue between the Service Program Office and the contractor should be encouraged during competitive Concept Formulation/Demonstration and Validation phases. Forthright debate of the issues and trade-offs are necessary to make readiness requirements fit the reality of development and meet the production and equipment fielding schedules.

3. Cost/Schedule/Performance Achievable with Known Technology

The level of technology should be clearly established, and advanced technology with its attendant risks should only be used when the payoff warrants. Increased performance dictates a higher price.

4. Don't Overspecify

"How-to-design" technical specifications should be excluded. The end goal is to satisfy mission needs by meeting established operational thresholds. Early integrated operational test and evaluation should be established to mutually satisfy customer/contractor test requirements and demonstrate that the equipment under development can be operated, maintained and supported within the sphere of military operations. Joint contractor, Service and OT&E teams can frequently satisfy this objective during development without costly delays. The use of commercial practices would help reduce development costs.

5. A Good Plan Before FSD

A tailored cost/schedule planning and control specification (C/SPCS) should be generated so that the realism of the schedule and costs can be evaluated.

6. Avoid System Level Prototyping

During Concept Formulation/Demonstration and Validation phases, the contractor should be required to establish a production prototype design and do such breadboarding and simulations as required to permit the Service to truly evaluate his offering. Demonstration and Validation should be accomplished at the lowest possible level-breadboard, brassboard, subsystem, simulation or system level — that is required to validate a new concept or reduce the risk of a new technology being introduced into full scale development (FSD) to an acceptable level. Flexibility in choice should be maintained. In the unusual event that a system prototype is required, it should be to the production prototype design. The adequate validation of technology at the proper level can help shorten full scale development and reduce costs.

7. Producibility, BIT, and O&S Established Prior to FSD

Producibility, built-in-test (BIT), maintenance and support concepts and tradeoffs should be thoroughly studied as an integral part of the design process. BIT should also be compatible with a reasonable maintenance concept and not specified at such high system or thoroughness levels that it dominates the design, is technically unachievable, or not cost effective. Life cycle cost (LCC) analysis should be used as an effective tool for shaping program plans and making product design decisions.

8. Fit the Design Environment to the Equipment

The electronic design environment (temperature, vibration, shock, access, volume, etc.) should be more completely defined to permit sound engineering for reliability, maintainability and support. Critical environments such as temperature, vibration, cooling, etc., should be measurable when BIT indicates an inflight failure so that the failure environment can be simulated on the ground in the event that the failure is not repeated on an ambient test bench (20-50 percent of failures are not).

9. CERTS or TAAF versus MIL 781

MIL-STD-781 on reliability testing by and large has been a failure for two reasons:

a) the environments are not realistic, and

b) the contractor and the Service Program Office have a mutual interest to pass, thereby defeating the punitive nature of the test.

Work at AFFDL on Combined Environments Reliability Testing (CERT), recent emphasis upon designing for reliability, and the Navy non-punitive Test, Analyze and Fix test (TAAF) concept with realistic test environments are far more likely to result in reliable hardware in the field.

10. The Parts Revolution versus Obsolescence

The number of electronic part types should, of course, be minimized, but current government inventory parts lists of active components should not be specified since they will be overtaken by technology by the time the system is in production and operation (i.e., FSD 4-6 years; plus production 4-10 years; plus support 10-20 years). However, when appropriate, the use of standard (MIL Spec and commercial) non active and perhaps some active parts with proven performance records can avoid development risks and benefit downstream logistic considerations. Again, flexibility in choice should be provided the designer through the tradeoff process.

11. A Mature Design in FSD

The Initial Operational Capability (IOC) date and program plan should be established on the basis that permits a mature design to be available at the completion of full scale development. It should be noted that the overall effect of a properly conducted Concept Formulation/Demonstration and Validation, as previously described, will not delay IOC, but in fact result in assuring that IOC will be met.

The continued use of competition and extensive candid face-to-face contractor/customer dialogue on cost, schedule and performance tradeoffs can provide agreement on performance that can be accomplished within schedule at an affordable Life Cycle Cost. With them the length of the acquisition cycle is shortened and acquisition costs are reduced. Here again, the Maverick procurement demonstrated a rapid transition from initiation to operational use when compared to today's lengthy acquisitions.

12. Minimum Cost Through Realistic Budgeting

The government can further assure shorter procurement cycles and reduced costs by establishing reasonable budgets that provide contingency funds to cover unforeseen problems, changes in performance, requirements, and threat as currently practiced by the Army with "TRACE" funding. The Service should work with the contractor to figure out what the desired system will actually cost and provide realistic budget information to Congress.

This will permit maintenance of program continuity thereby minimizing cost and schedule overruns.

13. Service Program Office Stability

The Air Force policy at ASD of integrated, co-located vertical SPOs including all business, engineering, logistic and support, and operational functions has been highly successful and should be continued. There should be documented guidelines (contracts) between the Service Program Manager and his management with sufficient flexibility that would permit him to make the day-to-day decisions and value judgments required to maintain the momentum and efficient prosecution of the program. The Service Program Manager should be professional in this difficult specialty and retained, as a minimum, for the duration of the development and initial production phases.

14. Delegation of Authority for Development

Responsibility for program execution should be delegated via the contract to the contractor. Reporting should be minimal, consistent with the Service Program Manager being on top of the program and able to recognize danger signals and take timely corrective action. Monthly program reviews that require 25 to 30 percent of the contractors' key personnel time should be forbidden. Major preliminary, critical, and other specified design reviews and major milestones are, of course, mandatory. Timely decisions on all issues are key to any successful program. Response time should be spelled out in the contract.

15. Benefits of 20/20 Hindsight

Since neither the contractor nor the government has total insight in establishing the perfect contract, a meaningful Value Engineering clause should also be mandatory. The world environment today introduces many uncertainties relative to energy, critical materials and economic escalation. Reasonable terms and conditions for any long duration contract should provide for these contingencies.

III. PRODUCTION

1. Design Maturity in FSD — a Key Factor in LCC

Prior discussion focused on the importance of properly using the design and development process to set the stage for production and deployment. Considerable emphasis was placed on the "selective" use of both state-of-the-art and advanced technology; upon designing for reliability, producibility, and the optimum support concept prior to full scale development to permit achieving a mature system design during full scale development.

With a few exceptions, such maturity has not been achieved. The result has been immature hardware entering production, high change rates, and the delivery of multiple configurations of tactical equipment. As a consequence, fielded hardware is difficult to maintain and support. Spares are inadequate, field and depot test equipment requires modification to retain effectiveness, and field modification must be used to ease the configuration burden.

As a result, costs are higher than predicted, operational readiness is put in jeopardy, procurement is stretched, and further cost increases are frequently encountered.

In seeking a solution to the achievement of design maturity, DOD evolved the concept of full-scale system prototyping and eliminated concurrency to reduce risk. However, the process of incremental decision making and multi-layered review has also significantly extended the acquisition cycle. The longer cycle results in too little, obsolescent and costly equipment in the field. The effect has been a decrease in readiness due to the doubling and tripling the "requirement-to-fielding" times for new systems and equipment.

Based on achieving a well thought out program prior to initiation of FSD and the attainment of a mature design in FSD, a number of changes can be made in the production phase to reduce cost and improve read' ss.

2. Concurrency Is Good

With a stable design of predictable cost, the acquisition can proceed smoothly. Concurrency for initial procurement phases during the latter phases of FSD can move forward in a cost effective manner, avoiding the multiple start up costs of the noncurrent program. Design of production tooling, special test equipment and long lead time material are all appropriate in the latter phase of FSD. One can and should expect lower production support costs and lower production hardware costs.

3. Multiyear Options

Multiyear options should and can equitably be negotiated, so that stability in production can be achieved. Such stability should save from 10 to 30 percent, depending on how close the chosen production rate is to optimum.

4. Continuity Pays Off

The point is that the Service and contractor managements will be devoting their time to managing a stable program rather than estimating in a "what if" environment. OPTIMUM AND PREDICTABLE RATES PAY OFF.

Examples:

a) 17,000 Maverick missiles in a total package program were procured in three options (doubling the procurement span was estimated to increase the cost 30 percent without considering escalation).

b) A program to produce 700 F-18 radars in 4 to 5 years is 25 to 30 percent cheaper than in 8 to 10 years.

5. Procurement — Multi-Year Buys for Cost and Reliability

Procurement provides another area to achieve cost savings with reliability enhancement as an added benefit. Currently the purchase of military grade electronic components is complicated by several factors:

a) Government quality surveillance of component suppliers is poor.

b) MIL-Spec requirements in conjunction with the relatively low volumes involved in most government contracts are not attractive to most component suppliers.

c) Large commercial buys for computers, the automotive industry, television, etc., are far less stringent in requirements and much more lucrative.

What can be done to improve this situation? Let us examine some possibilities based on a mature design:

a) Multiyear buys (our studies indicate that 30 percent can be saved by buying three years in lieu of one).

b) Tighten up on the quality control of the suppliers — many contractors are going to 100 percent incoming inspection with substantial capital and receiving costs.

c) Eliminate the requirement for multiple sources except where the technology or process is marginal (savings in qualification costs and savings due to higher volume will result).

d) Combine spare and production component buys.

e) Where feasible, buy from a single lot and verify quality through sample test (see b above).

f) Where quantity of a component used per system is low, buy out for all production plus spares.

g) The critical part of an active component, such as an IC, is the chip or dice which represents only a few percent of the component cost. Look at the potential of buying entire production and spare requirements via wafers thus avoiding obsolesence and providing protection against loss of the production process.

The effect of such procurement techniques is to save cost, minimize infant mortality, and accelerate reliability growth in the field, especially when combined with modern automated production, and carefully designed and controlled screening tests with appropriate environments at the module, black box and system level.

IV. OPERATION AND SUPPORT

DOD policy says O&S cost is an equal partner with performance and schedule. This is good policy for several reasons. First, there are today, less dollars available to buy the new hardware necessary to satisfy mission needs. Second, the continued growth in the cost of resources to operate and support the existing inventory is consuming the budget. Third, it forces the search for possible cost savings during new developments. The major goals of this concept are to reduce O&S costs below the acquisition portion of the budget without compromising mission reliability and military needs.

The DOD approach to achieving these goals at the policy level is to manage the Life Cycle Cost (LCC) of the system. With a few exceptions, however, this approach is not achieving the goal of cost/performance/schedule equality. The result has been continued emphasis on performance and schedule by the developers during the acquisition phase and continued requirements for traditional operations and support by the users. The gap between policy and practice is widening, and the concept will continue to lose credibility if steps are not taken to reverse the trend.

Several concerns may be causing the developers and the users to resist implementation.

A major issue to the developer is the budget. With less dollars available, the program is shaped for accomplishment of hardware design, development and test. Early life cycle cost and logistic activities are either not included, deferred at the first budget crunch, reduced to meaningless significance, retained inhouse by logistic elements of the military technology centers, or all of the above.

Another issue may be a lack of confidence in the results of O&S analysis due to concern for either the tools available or the soft engineering data used for early analysis. However, the models used have been verified through proven performance; and analysis is performed incrementally as the data base hardens. Each iteration permits a degree of depth and consideration consistent with the decisions required for that phase of the program.

A further concern may be doubt that reliability goals can be achieved. There are three major approaches to addressing this problem. First, new avionics technology is truly reliable and promises even greater improvements in the near term. Second, current techniques and test concepts are yielding higher reliability components and systems with earlier design maturity. Third, design failure predictions are derated to derive operational failure predictions reflecting both equipment maturity and support system maturity.

Still another problem is the military and economic concern of the user related to Phased Logistic Support, Warranties, Contractor Support, and other departures from traditional concepts. It is important to recognize that without major changes in maintenance philosophy and tables of organization no substantial savings can be realized in O&S costs and the long term goal of having the operations portion of the DOD budget less than the acquisition portion of the budget can not be met. The risk, however, is not as great as advertised or feared. Many support alternatives have been used by the military on a selective basis without loss of capability and at reduced costs. Others are used by commercial organizations with increased effectiveness and less expense.

Since the tools and knowledge to bridge the gap between policy and practice exist, they should be implemented. A simple, three-step conceptual approach would be to establish the requirement; provide the budget; and implement those alternatives that offer cost savings at no decrease in operational effectiveness.

The only practical way to establish the requirement is to have each Request for

Proposal, Statement of Work, and Contract include positive Integrated Logistic Support (ILS), Life Cycle Cost, and Reliability/Maintainability programs consistent with the needs of each program phase. It should start with the concept Formulation Phase and be reasonably definitized by DSARC II prior to start of FSD. These should be contractor conducted programs accomplished in conjunction with hardware design activities. The resulting analyses should help shape the hardware designs for cost avoidance and ease of maintenance. ILS/LCC requirements, based on the design configuration, should be reviewed in face-to-face encounters with the customer, and agreements reflected in program specifications, plans and contractual documents. There is a revolutionary potential for reduction in O&S costs due to:

a) the ability to achieve design maturity in development per earlier discussion;

b) substantial reduction in infant mortality by new production screens from the component through the system level;

c) improved BIT.

In fact the potential exists for eliminating Intermediate and organic Depot Level Maintenance (i.e., use factory support).

The key is adequate front end funding for the Concept Formulation through Production plus a firm determination to apply the principles previously presented. Equivocation will lead to the sad results of the past.

The concept of support alternatives requires different treatment due to the varying claims made for and against their use. One approach is to graphically put some dimensions on the discussion. Figure 1 provides a standard definition for life cycle costs and describes a relationship between cost categories and program phases. The areas of interest to this discussion are acquisition costs and ownership costs. Note that phased logistic support would occur during the span called Contractor Support Cost and req[illegible]es overlap to transition to organic su[illegible]. A full contractor support program or warranty program would replace organic support for the span shown if either were to be selected as a cost effective alternate.

Figure 2 verifies the earlier discussions on development. Subsystem configurations are frozen prior to Demonstration and Validation; system and production feasibility is proven prior to Full Scale Development; a mature design is available prior to Production. Note also that analysis after Concept Formulation can only affect 30 percent of the LCC commitment. After Development, it is possible to affect only 5 percent of the cost. Consequently requirements for ILS/LCC programs must be clearly defined in early RFPs. The government needs to work closely with the contractor during early phases if the desired cost savings are to be realized.

DOD is encouraging the use of technology to lower Life Cycle Costs. The biggest cost drivers in the process are reliability, expressed in mean time between failures, unit price, and people. While all three are design relatable, only the first two can be controlled by the contractor. The third is a function of the government, consequently there is a finite limit to the cost savings available through technology. Cultural changes are required to realize full benefit.

A typical modern airborne radar using the latest technology exhibits an LCC distribution of 67 percent for acquisition and 33 percent ownership as illustrated in Figure 3 using conventional three-level support. Traditional support concepts yield non-recurring costs of 53 percent and recurring support costs of 47 percent. Further percentage breakdowns for each category show the biggest cost drivers to be people and spares, with support equipment also contributing heavily to initial costs.

Combining various AGE and maintenance concepts permits studies to be conducted that compare life cycle logistic support costs for candidate support concepts. Figure 4 defines a family of support alternatives that offers cost savings when compared to the conventional three-level maintenance concept.

Principal design decisions include the consideration of a suitcase tester in lieu of expanded BIT capability to isolate faults within a replaceable unit (and in many cases to a single replaceable assembly) and consideration of functional partitioning approaches permitting the removal of replaceable assemblies at the organizational level.

As illustrated, a two-level maintenance concept with contractor support at depot level offers 50 percent cost savings over the conventional baseline concept. With savings of this magnitude available, the government must urge the services to implement the cultural changes necessary, and it should be done rapidly.

V. SUMMARY

If generally applied across DOD procurements of systems and equipment, the principles that have been presented should lead to significant gains in Life Cycle Cost. The paper emphasizes that to seriously impact LCC you must:

- Establish an Integrated Service Program Office with responsibility and authority to

make timely decisions and the longevity to maintain continuity throughout the acquisition process.

- Have extensive forthright communications and negotiations between the competing contractors and the Customer through the Concept Formulation/Demonstration and Validation Phases to establish a viable contract for FSD.

- Establish the realism and risk of the proposed concept at the lowest level of testing, analysis, and simulation of critical subsystems; a production prototype design; and a detailed program plan prior to FSD.

- Maximize the use of known technology appropriate to the application with a dedicated plan to achieve a Mature Design in FSD.

- Adequately fund all phases with reasonable contingencies for changes in requirements, unforeseen problems, etc., via a realistic independent estimate of the expected cost by the Service based on past weapon system procurement history.

- "Utilize Best Economic Buy" in establishing production rates and multiyear procurement of components.

- Maintain reliability in production and minimize infant mortality by optimum procurement policies, and environmental test screens appropriate from the components through the system level.

- For modern avionic systems designed and built to the above concepts, establish a two level O&S concept (i.e., "O" level remove and replace subsystems; piece part repair by the contractor).

- Maintain program continuity with concurrency determined by reasonable risk.

These principles support the concepts and requirements of OMB Circular A-109 and associated DOD directives. Achievement demands substantial changes in Acquisition and Support Policy by the DOD and Congress, plus dedication by the industry to back up their convictions with performance.

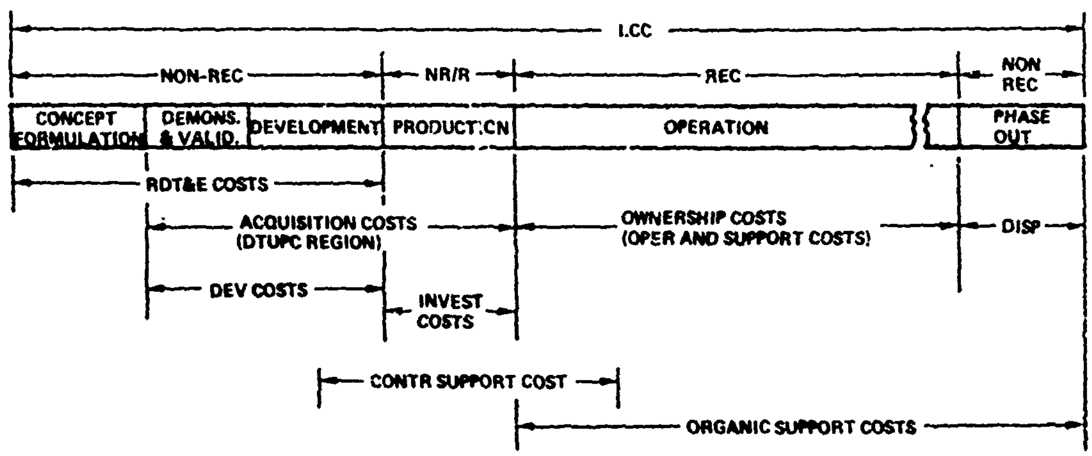


FIGURE 1

LIFE CYCLE COST — A STANDARD DEFINITION

51

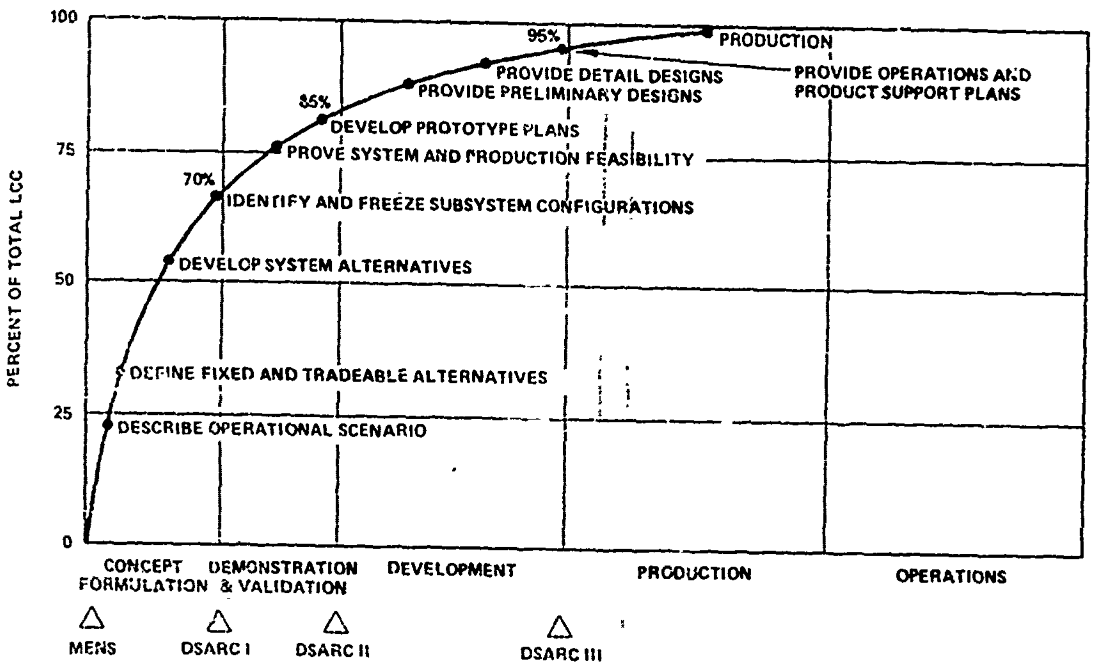


FIGURE 2

LIFE CYCLE COST COMMITMENT

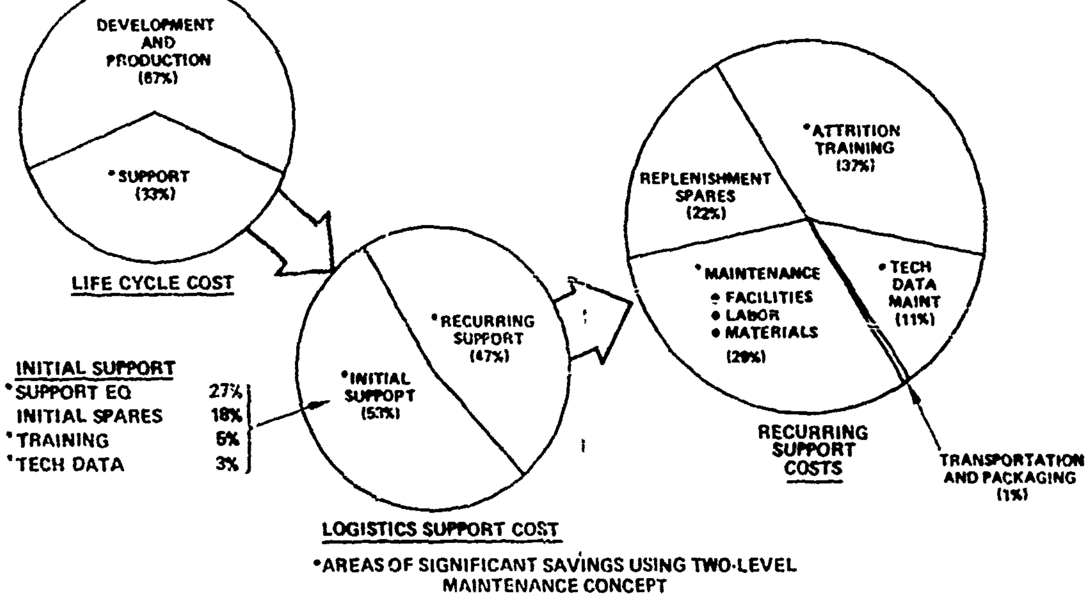


FIGURE 3

TYPICAL MODERN RADAR LIFE CYCLE WITH 3-STEP SUPPORT COSTS

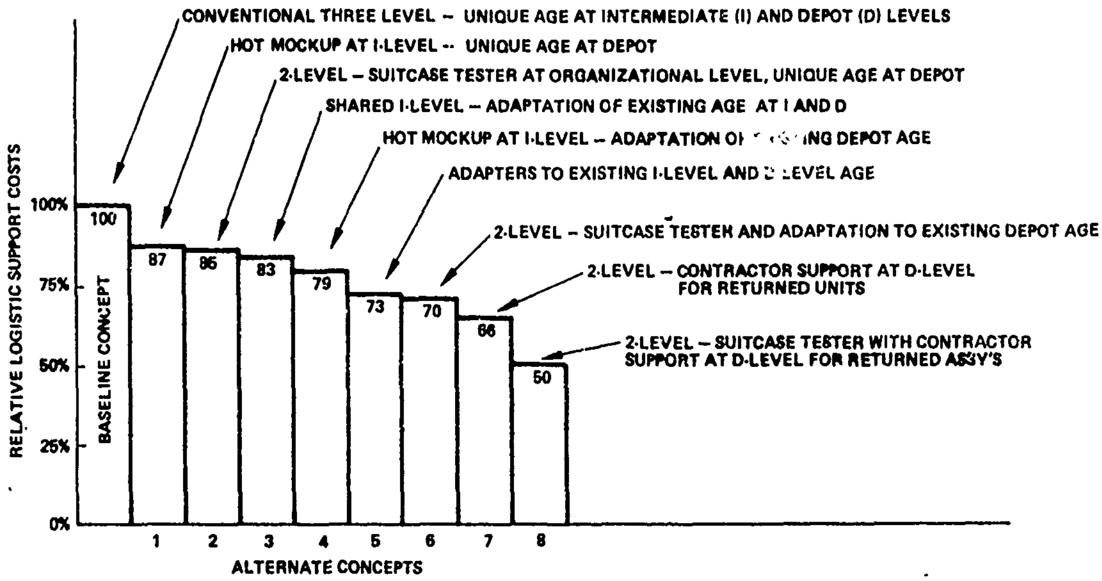


FIGURE 4

COMPARISON OF LOGISTIC SUPPORT COSTS FOR TYPICAL RADAR ALTERNATE SUPPORT CONCEPTS

LIFE CYCLE COSTING EXPERIMENTS AT THE FEDERAL SUPPLY SERVICE

Paul Browne, General Services Administration
Peter Unger, ETIP, National Bureau of Standards

ABSTRACT

This paper presents the results of an initial series of life cycle costing (LCC) procurement experiments conducted by the General Services Administration, Federal Supply Service (FSS) in cooperation with the National Bureau of Standards. Experimental Technology Incentives Program (ETIP) for the dual purpose of getting better value for the procurement dollar and encouraging product innovation. Air conditioners, refrigerator-freezers, water heaters, and gas and electric ranges were the products bought under the LCC concept. These contracts were awarded based upon the bid price plus operating cost estimates. Since these experiments began in 1974 an estimated two million dollars have been saved in awarding these contracts using LCC.

LIFE CYCLE COST (LCC) TECHNIQUES FOR MAJOR ACQUISITIONS

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ABSTRACT

This paper presents our experience and results of applying LCC cost analysis techniques on major system acquisitions. We emphasize practical application of costing techniques for decision making early in the life cycle of a program. Key topics of the paper include:

I. Life Cycle Cost Data Base.

a. Data base development methods.

b. Cost estimating relationships; development and use.

c. Historical cost data sheets; tools for estimates by analogy.

II. Life Cycle Costing Techniques.

a. Parametric methods of LCC estimates

b. Multiple independent estimate approach to LCC estimates.

c. LCC cost trade study techniques that identify lowest program LCC.

III. Results of Application of our Life Cycle Costing Techniques.

a. This part of the paper presents examples of costing techniques we have found useful in cost analysis of recent major system acquisitions.

b. LCC profiles that provide the relative cost significance of major system elements.

c. LCC cost driver lists identify those few items that capture the majority of the program LCC.

d. LCC trade matrix we developed as a technique to standardize cost results for the decision making process.

e. Cost sensitivity analysis techniques we have used for trade studies and decision making.

f. Lessons we have learned performing LCC analyses on acquisitions.

CONTRACTUAL INNOVATIONS IN LIFE CYCLE COST APPLICATION

Captain John M. Barry, USAF Acquisition Logistics Division

INTRODUCTION

Procurement/acquisition concepts, such as life cycle costing and design to cost (LCC/DTC) progress through various stages in the implementation process. This process starts with the basic procurement regulation and develops into specific guidance tailored to the contracting environment. Then the concept undergoes large promotional campaigns through professional symposiums and contractor advertisements. In life cycle costing and design to cost, these promotional campaigns are evidenced by the large number of seminars and symposiums devoted to the subject. These seminars do fulfill the urgent need of dispersing information to top level management in DOD and industry on LCC/DTC but they fall short on meeting the need for specific practical implementation at the contractual level. This level involves the middle manager, cost analyst, and the design engineer. These individuals actually implement and determine life cycle costs through their decisions and design of equipment. They desperately need the proper and simplified tools to apply LCC/DTC. Unfortunately, the information given in most seminars on LCC/DTC is either too broad in scope, more promotional than practical, or just too tailored to specific companies to be of any benefit to the design engineer. Furthermore, the LCC/DTC methods being developed or presently used are becoming rigid, paper consuming and cumbersome systems which are creating their own bureaucratic self-defeating empire. This empire is contrary to the LCC/DTC basic purpose which is to motivate these working level individuals to consider life cycle costs in the development of the system. The problem of motivating these individuals to actually consider life cycle costs in their decisions is not being solved.

Experience in LCC/DTC auditing has indicated that we are not properly educating the design engineers or cost analysts on the essence of LCC/DTC - that is to r ate design/performance parameters to life cycle costs. Instead, we are burdening them with cumbersome LCC/DTC paperwork, and reporting requirements which detract from their engineering and cost tasks. This additional workload is not only detrimental to the development of new systems, but also may cause LCC/DTC to die under its own bureaucratic paperwork much like the "ilities" suffered from over-promotion and overemphasis in the early '70s. Therefore, some tool or procedure must be applied to LCC/DTC in the contractual process which is meaningful to the middle manager, design engineer, and cost analyst which fulfills the need of LCC/DTC. This tool is the programmable calculator, a portable, relatively inexpensive and easy to use device that can be used in the LCC/DTC process.

This paper will focus on the concept of using programmable calculators in LCC/DTC as well as actual contractual experience and benefits derived from its application. Programmable calculators have achieved a level of sophistication which allows comprehensive analysis to be performed on them. LCC/DTC contractual modeling requirements formerly restricted to large scale computers can now be effectively accomplished with these calculators. The advantage of applying programmable calculators is that the contractor can be given pre-developed or he can develop, with government approval, LCC/DTC models which require no knowledge of computer/calculator programing. Given these models anyone - the middle manager, engineers, and cost analysts, can apply LCC/DTC with the same facility required to operate a four-function calculator. This paper will expand the discussion on programmable calculators to include a simplified description and provide an educational overview of standard Air Force LCC/DTC models which are successfully used on present contracts and demonstrate the value of programmable calculators in the acquisition process.

THE PROGRAMMABLE CALCULATOR AND ITS APPLICATIONS

Inherent to the concept of a programmable calculator is a precise definition and a certain level of computation sophistication. Such a calculator can be defined as portable instrument which is capable of performing and storing complex repetitive operations involving logic and branching instructions. These operations include addressing, branching, variable/operation storage, looping and modularity. All of these features are essential to the concept of programmable calculators. Calculators which exhibit only some of these features are not sufficient to accomplish the demanding requirements in Life Cycle Cost/Design to Cost (LCC/DTC). Even with this description there are varying levels of sophistication among programmables. The most useful features are those calculators with "non-volatile" memory. This memory refers to an electronic or magnetic device which retains the program and data contents even when the calculator is turned off. The limitations of the electronic non-volatile device is that the memory capacity is restrict-

ed to the maximum number of programming steps/storage locations the calculator can accommodate. The magnetic device card which is inserted and read into the calculator, is much more versatile. Separate programs/data can be stored and retrieved on individual magnetic cards. This allows the user to build and retain a large library of LCC/DTC programs for different applications. These applications will be explored in further detail in the following paragraphs.

Prior to describing the programmable calculator LCC/DTC applications, a depiction of the range of functional possibilities is necessary since life cycle costing is an interdisciplinary subject. The manufacturers of programmable calculators offer predeveloped software programming packages in the various functional areas of statistics, engineering, business, systems analysis/operations research, physical/life sciences, and many others. The complex programs in these various areas formerly restricted their solutions to large scale computers. The advent of programmables allows the computation of such problems such as learning curves, reliability predictions, trend forecasts, and multiple regression analyses in the matter of seconds. While it is true that these problems can be solved with a scientific handheld calculator, the time and error possibility required of any task using a programmable is greatly reduced. Therefore, the programmable remains as a desirable and in many cases cheaper alternative to the time-consuming handheld calculator or expensive large scale computer for solving a variety of problems in various functional specialties. This alternative suggests the relevance of effectively using these calculators in the system acquisition process.

Opportunities for constructive application of the programmable calculator exist through the entire system acquisition process. During the conceptual phase when detailed data is not available, parametric model development is essential. Parametric equations relate variable or constant performance or design data to cost in the LCC process. A simple example of a parametric equation could be the relation of weight to transportation cost, i.e., transportation cost = $.13 per pound x total weight. More complex examples such as those relating some performance parameter like reliability to cost may involve literally pages of equations which can be effectively accomplished on this calculator. As system development progresses into the validation phase, design to cost models can be employed on these calculators thereby greatly simplifying the amount of effort required at the design engineer's level. Further applications are possible when a system transitions into the full scale development and production phase of system development. Models involving learning curves, probability distributions, and economic order quantities are used to solve production should cost problems, spare requirements, and design to cost goals. Therefore, the programmable calculator can be applied over the entire spectrum of the system development cycle. Next, specific applications in the LCC/DTC process will be explored.

The essence of a good LCC/DTC model should relate some design performance parameter to cost. Performance parameters are usually selected because operational costs which often consume from 60%-85% of a systems total LCC, are dependent on these parameters. Such a parameter is reliability. We know that the more reliable a system is, the less maintenance and spares it will require, thus reflecting lower operational costs. However, this increased reliability is not free - it costs extra and must be factored into a life cycle cost model. The extra reliability cost is usually determined by front-end or development models which relate reliability to development and production costs. These development models are usually program unique. However, the operational models that determine reliability cost differences normally trace their origins to the Air Force Logistics Command (AFLC) Logistics Support Cost (LSC) model or the counterpart models in the Navy and Army. Since the LSC model has been successfully employed on programmable calculators in numerous Air Force and some commercial contracts, this model will be described in more depth and demonstrated on the calculator.

The objective of the AFLC Logistics Support Cost (LSC) model is to estimate the support costs that may be incurred by adopting a particular design for a given weapon system or a piece of equipment. The model is intended for application in source selection and in contractual design of hardware. In source selection the LSC model is used to obtain an estimate of the differential logistics support costs between the proposed design configurations of two or more contractors. During hardware design, the model serves as a decision aid when discriminating among design alternatives.

The LSC model consists of ten equations, each of which represents a component of the total cost required to operate the logistics system. These ten components are:

1. Initial and replacement line replaceable unit (LRU) costs. An LRU refers to a component like a radio, initial guidance system, etc., which can be removed, replaced, spared, and maintained as an integral unit.

2. On equipment maintenance cost is that cost attributed to working on an LRU while it is still attached to its system. For example, the calibration cost of a radio while it is still installed in the aircraft falls into this category.

3. Off equipment maintenance cost refers to

the maintenance performed when the LRU is removed from the system. For example, alignment of an inertial navigation system at an intermediate or depot repair facility is considered such a cost.

4. Inventory and supply management cost.

5. Support equipment cost refers to the equipment costs required to maintain an LRU. For example, calibration sets, voltmeters, would be included in this category.

6. Cost of personnel training and training equipment.

7. Cost of management and technical data.

8. Facilities costs.

9. Fuel consumption cost.

10. Cost of spare engines.

The first seven equations are evaluated for each appropriate LRU and the results are collected over all subsystems. To arrive at a logistics support cost for the total system, the last three equations are added. Although this model was originally developed for aircraft systems, it has been adapted to space and missile systems by eliminating equations 9 and 10.

The running of the LSC model requires some 60 variable inputs and the computation of approximately ten pages of sophisticated equations. The model could be performed on a handheld scientific calculator, a large scale computer or a programmable calculator. The performance of the model on a scientific calculator would take about three hours for one problem. The model turnaround time on a large scale computer sometimes is not any better because there are computer delays related to computer downtime, keypunching, and facility location. Therefore, both the scientific Calculator and computer tend to drive up the commodity we are most interested in making more efficient - engineering labor on development contracts. However, the programmable calculator avoids all these pitfalls by providing the design engineer with a personal tool which he can perform and record LCC/DTC requirements. A demonstration of the speed and accuracy using the LSC model on a programmable compared against the other two computational methods will indicate the value of this calculator in the LCC/DTC process. The comparison data presented in Table 1 is based on actual audits performed.

TABLE I

COMPARISON OF LSC PERFORMANCE ON VARIOUS COMPUTATIONAL DEVICES

Computational Device	Average Steps Involved	Average Time Involved	Est Input Error Rate
Scientific Calculator	1. 3,150 keystrokes	3 hours computation	65%[1]
	2. Documentation of Intermediate & final reviews		
Large Scale Computer[3]	1. Input data on keypunch forms	3 day turnaround	20%[2]
	2. Send to keypunch		
Programmable Calculator	1. 20 keystrokes		15%
	2. Paste output on preprinted form		

1. Error rate due to incorrect keystroke input.

2. Error rate due to a combination of incorrect entry on keypunch form and keypunch operator error.

3. Refers to off-line computer operation.

The analysis of the error rates in Table 1 illuminate some of the complexities in using these computational devices. If an error is introduced in performing LSC on the scientific calculator, the entire procedure has to be repeated with a time loss of 3 hours in one case and a delay of 3 days in another. The three-day turnaround can then be related into a schedule loss and increase contractual costs. Even through the error rate on the programmable calculator is not much lower than on the computer, the mistake is rectified in 2 minutes versus 3 days. Therefore, reduced time and increased convenience and availability can be an important factor in the programmable calculator's contribution to productivity and cost reduction. These decreased costs have been realized on some present contracts. For example, one contractor demonstrated a net cost avoidance of $158,000 through the use of programmables on LCC/DTC tasks. In addition, there are some attractive qualitative improvements to the LCC/DTC process that this calculator has introduced.

The qualitative improvements realized from programmable calculator application have enhanced the LCC/DTC performance. These improvements include increased integrity, acceptance, analyst motivation, streamlined documentation, and LCC being worked at the design engineer level. LCC audits indicate that prior to the use of programmables, some design engineers actually developed their own simplified formulas that could be computed on a handheld scientific calculator rather than use the more time-consuming large scale computer. These engineers reverted to using the scientific calculator because it was more convenient and produced faster results. This situation not only compromised the integrity of LCC/DTC performance, but frequently produced incorrect results. The programmable provided these design engineers with a greater and more acceptable capability because it provided the same availability and portability as their own scientific calculator. This improvement not only increased the engineer's motivation to perform LCC/DTC but also reduced the documentation from several inches of computer paper to two simplified input/output sheets. The most spectacular benefit achieved has been that design trades are now being accomplished at the design engineer working level. Formerly these trades were relegated to either some computational or the finance department. These two departments are so far removed from the design engineering process in both function and motives that they are irrelevant to LCC/DTC. These qualitative improvements are yet another indication of the value of the programmable in LCC/DTC.

Several other models other than the AFLC LSC model have been applied to programmables on contracts with similar success. They include the optimum level repair analysis, economic analysis models, the National Aeronautics and Astronautics Cost per Flight for commercial users model, and scores of others. A description of the AFLC Logistics Support Cost Model was introduced to indicate the complexity and advantages of programmables. These additional models noted are equally complex and lend themselves to adaptation with this calculator. The power of this calculator is only constrained by the ability of the programmer. Large programs which exceed the memory of the calculator can be executed by dividing the problem into manageable pieces or subroutines and placed on magnetic cards. However, the programmer must keep in mind the user and simplify both operating procedures and execution time. The programmable is not applicable to massive data base problems. It is intended to be a valuable supplement, but not a replacement to the computer. The applications presented are only an indication of the power and advantages of the programmable.

SUMMARY

The concept, applications, experience and benefits of programmable calculators to the LCC/DTC processhave been explored. This paper examined some of the possible uses that this versatile tool has in LCC/DTC. The list of contributions to the contracting arena was equally impressive, especially in the area of cost avoidance, increased productivity and motivation. The current applications of the programmables are not intended to make the design engineer or cost analyst a programmer, but to provide this person with a preprogrammed tool that can be used in making designs which will reflect a decrease in life cycle costs. As long as this objective is pursued, the programmable calculator will continue making significant contributions in life cycle cost and design to cost. Finally, this calculator is not presented as a panacea to all engineering analyses required, but as a tool that has the potential to increase LCC/DTC productivity and reduce costs on development and production contracts.

PRODUCTION COST ESTIMATING

STRATEGIC IMPLICATIONS OF THE EXPERIENCE CURVE EFFECT FOR AVIONICS ACQUISITIONS BY THE DEPARTMENT OF DEFENSE

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Air Force Systems Command, United States Air Force

INTRODUCTION

This paper summarizes the author's doctoral research into the applicability and strategic implications of the experience curve effect for avionics acquisitions by the Department of Defense [3]. Experience curve theory seeks to explain product cost-quantity (or price-quantity) relationships in terms similar to those of learning curve theory, but recognizing the influences of such managerially controllable factors as investment, specialization and scale. This theory has far-reaching strategic implications for many aspects of business with the most significant centering on the dependence of profitability on market share. Department of Defense procurement agencies can improve their own strategic decisions by recognizing and considering the implications of the experience curve effect for aerospace industry firms.

The Defense Department has supported numerous studies of learning curve theory, mainly in the context of the airframe and aircraft industries. However, no research has yet been documented with respect to the applicability or significance of experience curve theory (as distinguished from learning theory) for either buyers or sellers in the relatively unique environment of the military market place.

Department of Defense procurements impose very extensive Government regulations on contractors, and the few-sellers, very-few-buyers (oligopolistic, oligopsonistic) defense market place differs markedly from the strongly competitive consumer and industrial markets examined in the light of experience curve theory by The Boston Consulting Group [2] and by Woolley [6]. For instance, defense procurements are usually made only in annual increments, authorized and funded at the discretion of Congress. The uncertainty thus surrounding future orders is a severe disincentive to capital investment, resulting in less than optimal efficiency and productivity. Productivity enhancement is further handicapped by the particularly rapid onset of obsolescence, unfortunately characteristic of the high technology products required by the defense community. Long lead-times between major project start-up and completion are the rule, not the exception. Non-standard designs are common, and the contractor's technical risks are multiplied by Government intervention in both product and process design changes. Urgency often dictates unusually demanding delivery schedules.

RESEARCH METHODOLOGY

Based on a review of the literature relevant to experience curve theory, and on the author's avionics acquisition experience, a set of seven related issues which warranted further research was identified. These issues are:

1. How do experience curves differ from traditional learning curves in the Government procurement environment?

2. How are the forms of experience curves affected by alternative techniques for compensating for the effects of inflation?

3. How are the forms of experience curves affected by implicit prior experience on closely related products?

4. How are the forms of experience curves related to production lot sizes, product delivery rates, delivery lead times, and the duration of breaks between production runs?

5. How stable are experience curve slopes over successive procurements?

6. How consistent are experience curve slopes within and across firms?

7. How accurately can future procurement pricing be predicted using experience curve theory?

These issues were investigated in the context of 361 selected Department of Defense avionics equipment procurements made from 1960 through 1976, representing 20 equipment items and 13 contractors.

The non-random selection of the data base content limited the utility of statistical tests, and transformation to logarithmic formulation distorted the usual interpretation of such established indicators as the Coefficient of Determination (R^2) and F-tests. In spite of these limitations, selective use was made of F-tests of explanatory significance, R^2 and Adjusted R^2 values, and Standard Error of Estimate (SEE) values in comparing alternative models. Examination of regression residuals played an important role in determining the applicability of models, particularly with respect to Issue 5. Other statistical tests of relationships, such as t-tests and chi-square tests, were also used extensively. Bivariate and multivariate regression were the main

analytical techniques used.

The models and variables used are summarized here. The classical (or traditional) power form model of learning or experience attributed to Wright [7]

$$Y_A = B_o X_1^{B_1}$$

and its logarithmic transformation

$$\ln Y_A = \ln B_o + B_1 \ln X_1$$

were used most extensively (Issues 1, 2, 5, 6, and 7). The modified power form model of learning attributed to Crawford [1]

$$Y_U = B_o X_1^{B_1}$$

and its logarithmic transformation

$$\ln Y_U = \ln B_o + B_1 \ln X_1$$

were used only in conjunction with the analysis of Issue 1. A variant of the classical power form model and of the Stanford-B equation [5]

$$Y_A = B_o (X_1 + C)^{B_1}$$

and its logarithmic transformation

$$\ln Y_A = \ln B_o + B_1 \ln (X_1 + C)$$

were similarly used only in one analysis, that of Issue 3.

A multiplicative variant of the classical power form model (similar in form to Levenson's model [4])

$$Y_A = B_o X_1^{B_1} X_2^{B_2} X_3^{B_3} X_4^{B_4} X_5^{B_5} X_6^{B_6}$$

and its logarithmic transformation

$$\ln Y_A = \ln B_o + B_1 \ln X_1 + B_2 \ln X_2 + B_3 \ln X_3 + B_4 \ln X_4 + B_5 \ln X_5 + B_6 \ln X_6$$

were introduced and used for the investigation of Issues 4 and 7. (This model is considered to have particular merit for future extensions to other data bases.)

The variables in the preceding equations are defined as follows:

Y_A = Cumulative Average Unit Price (or Cost)

Y_U = Unit Price (or Cost)

B_o = Imputed First Unit Price (or Cost)

B_1 = Learning or Experience Slope Exponent

B_2 through B_6 = Modulation Effect Exponents

C = Implicit Prior Experience Quantity

X_1 = Cumulative Quantity

X_2 = Quantity Bought

X_3 = Maximum Delivery Rate

X_4 = Production Break Duration

X_5 = Delivery Lead Time

X_6 = Average Delivery Rate

CONCLUSIONS

Issue 1. Analysis of the performance of defense avionics contractors indicates that price usually follows costs in the Government market place as it does in consumer and industrial markets, although with experience curve slopes typically of 85% to 95%, rather than the 70% to 80% observed in those latter markets. This relatively gradual rate of experience realization appears to be due both to the extent of Government interventions and controls, and to the concern of Government decision-makers for maintaining flexibility at the expense of productivity. For individual contractors, moderately significant predictive relationships were found to relate price experience slope to learning slopes for direct labor costs, purchased material costs, and total manufacturing costs. However, no significant relationships were identified at the sub-industry composite level, suggesting that price predictions based solely on industry average cost slopes are predestined to be inaccurate. In most instances, the best statistical fits of data to theory resulted when cumulative average experience curves were fitted to price data.

Issue 2. The performance of the three alternative deflators analyzed was generally quite similar, in terms of visible effects on the shape of graphically displayed data. Ignoring inflation was found to result in relatively flat slopes with pronounced perturbations; Gross National Product (GNP), Federal Purchases of Goods and Services (FPGS), and Avionics Procurement (AVPR) deflators yielded increasingly steeper slopes for the same underlying data, with fewer perturbations. This ordering of the deflators in terms of slope steepness was found to be statistically significant, with the least distinction between the two closely tailored deflators (FPGS and AVPR). Based on the relative importance attached to various performance measures (e.g., slope steepness, explanation of variance), any one of the three deflators may be slightly preferred

relative to the others for a particular analysis; only the alternative of ignoring inflation is consistently dominated.

Issue 3. Introduction into the traditional learning model of a positive shift factor, commonly thought to represent an implicit prior experience quantity, resulted in improved statistical fits in half of the procurement sequences investigated. In ten instances, the prior experience interpretation seemed reasonable. However, in six instances shift factors of 10,000 or more suggested the need for an alternative interpretation. In each of these six instances, continuing or threatened competition was a relevant factor which could have served as the impetus for the observed sudden and sharp break in the established pricing trend. Establishment of a causal relationship was beyond the scope of the present research. Since the coordinate transformation approach does not consider such experience factors as investment, specialization, or scale, it does not add to the explanatory or predictive power of experience theory (even though statistically better fits can result from shift factor introduction). Further pursuit of this coordinate transformation technique does not seem worthwhile; other models and additional variables need to be considered if prior experience is to be explicitly recognized.

Issue 4. Five production parameters were proposed as implicitly recognizing the experience factors of investment, specialization, and scale. In multivariate regressions, the effects of each of these five postulated production parameters were found to be beneficial in increasing explained variance and reducing the standard error of estimate in from five to eight different procurement sequences (of the twelve analyzed). In no case did a variable drop out of the regressions once introduced, and in no case did the sign of a coefficient change as additional variables were introduced. Cumulative Quantity (the traditional independent variable in learning or experience theory) was invariably the most significant contributor to the explanation of price shifts. Production Break Duration, Delivery Lead Time, and Maximum Delivery Rate were found to be the most significant modulating parameters, with no clearcut order of preference amongst them. Average Delivery Rate and Quantity Bought were also important. A surprising finding was that the apparent effect of extended Production Break Durations was usually to reduce, rather than increase, price. Competitive pressures cannot be credited, since continuing or threatened competition was not a factor in any of these instances. Two possible explanations would be that continuing production of similar products during these production breaks could have sustained beneficial experience trends, or that contractors may have used the breaks constructively to implement other cost reductions.

Issue 5. Slope change patterns were identified and evaluated in 15 of the 32 procurement sequences investigated. The commonest pattern (6 instances) involved only one break point, with an initial nearly level or gradually declining slope followed by a relatively steeper decline; this pattern is consistent with the experience curve effect implication that price should initially be set near costs, then decreased with costs (once a satisfactory profit margin is realized) to inhibit market entry by competitors. The second commonest pattern (5 instances) involved two break points, with an initially declining slope followed by a rising slope, followed finally by another decline. This pattern suggests that contractors encountered problems leading to higher than planned costs, overcame them, and continued to realize experience gains. An alternative view would explain this as a pattern of buy-in (price below cost) until the market is assured, increase price to a profitable level, then reduce price with costs to reduce the risk of competitive entries. Breaking each of these 15 procurement sequences into two or three log-linear segments resulted in statistically significant improvements in the fit of the models to the data; the most notable improvement was in the reduction of standard error of estimate magnitudes. The mean last log-linear segment regression slope for the nine procurement sequences demonstrating experience gains for that segment was 87.5%; this was substantially steeper than the 93.8% mean value of the overall regression slopes for these same nine sequences. This pronounced differential suggests that overall regression slopes may often be unduly conservative (i.e., too flat, thus overestimating prices), but also provides warning that projections based on piecewise log-linear regressions may be seriously understated if some unrecognized factors disrupt the segment trend.

Issue 6. Regression slopes were found to be highly variable both within and across firms. These findings strongly suggest the desirability of making multiple projections, using a range of potential slope values, when planning for new product introduction or for resumption of production following a major disruption (e.g., extended break, facility relocation, product or process redesign). Since slopes were not found to be consistent even within firms, let alone across firms, arbitrary reliance on any one slope value for forecasting purposes, whether believed representative of the product line, the firm, or the industry, should be avoided. Development of forecasting models which expressly recognize relative product complexity and a contractor's overall experience level should offer opportunities for improvements relative to the current traditional models, reducing dependence on learning slope identification and prediction.

Issue 7. For the twelve avionics data subfiles

analyzed, the predictive abilities of all four methods tested were surprisingly good (i.e., deviation values were less than 5%). The results achieved with the last log-linear segment methods were found to be more statistically significant than those achieved with overall regression methods, testing on percentage-based performance comparisons. The production parameter overall regression method was significantly better than the traditional overall regression method only in projecting prices for the second buy beyond the range of the model data; the last log-linear segment production parameter regression model was never demonstrated to be significantly better than the last log-linear segment traditional regression model, even though dollar-based measures (not amenable to statistical tests) appeared to favor it as the best of the four methods. Significance tests not withstanding, in view of the seemingly good performance of the production parameter models in reducing standard error of estimate values, and as indicated by dollar measures, these models warrant further investigation and refinement.

PROCUREMENT RECOMMENDATIONS

This concluding section provides recommendations for both buyers and sellers in the defense market place. These recommendations are based mainly on the two major findings in the present research: 1) Experience curve theory is applicable to Government procurements, but 2) The rate of realization of experience is less than in consumer and industrial product markets. Recommendations deriving from the first major finding are presented from the perspective of interpretation of general business strategy implications. Recommendations deriving from the second major finding are presented from the perspective of implications for buyer-seller interactions. Each of these perspectives will be further introduced before proceeding with the actual recommendations.

The present research has confirmed that price usually follows cost (i.e., total manufacturing cost) even in the unique environment of the defense market place. Consequently, it is appropriate to interpret the general business strategy implications of the experience curve effect in the context of military procurement. Recommendations relating to business strategy will be presented grouped around five core ideas: Price and Competitive Interaction, Technology and Market Share, Product Growth Rate, New Product Introduction, and Procurement Planning and Negotiations.

Consideration of buyer-seller interactions offers a more useful perspective for the remaining recommendations, based on the finding that experience realization is more gradual in the defense market place than in consumer and industrial markets. This fact may be attributed in part to the extent of intervention by the Government customer in decisions which, in other markets, would be within the purview of the producer. Additionally, it is due in part to unique aspects of the defense market place which affect producer risks, reduce incentives, and inhibit productivity gains. These explanations provide the framework for further recommendations. Emphasizing buyer-seller interactions, these complementary recommendations will be structured around four core ideas: Government Intervention, Producer Risks, Producer Incentives, and Productivity Inhibitors.

With a focus on business strategy, consider first the idea of price and competitive interaction. Experience theory holds that market instability develops when price does not follow cost. In openly competitive markets, instability leads to a price break, followed by a shakeout of marginal producers until price again stabilizes near cost, resulting in lower prices for customers and reduced profit margins for the surviving firm. In the military market place, similar patterns occur when there is open competition, but open competition is rarely maintained. Usually, once a firm wins an initial competition for a new military avionics product, it can expect to receive follow-on orders for added quantities in future years, provided technical performance is adequate and price does not increase more than is justifiable as being due to inflation. Given the nature of Government contracts and the limitations imposed on profits, competition provides contractors with the only real incentive to reduce costs and thus prices. In the absence of product standardization (i.e., form, fit, and function standards), there can be little meaningful continuing competition, and premium prices are paid to a sole source. While this pattern of action can sometimes result in minimum life cycle costs to the Government, it should not be accepted automatically as the normal way of doing business. Future designs for common avionics equipment should be required to meet form, fit, and function standards. This would permit effective production competition, when warranted, and would also simplify future equipment retrofits. Further, even without competition, increased standardization is conducive to greater productivity. Sellers (particularly those seeking sole source contracts) should concentrate on demonstrating their ability to reduce costs and willingness to reduce prices even in the absence of competition.

With respect to technology, investment in research and development provides a competitive edge to firms competing in consumer and industrial markets. Although the Government funds much military research and development, firms competing for military business should likewise seek a competitive edge by investing their own resources, both in anticipatory pre-proposal

work and in more formalized independent research and development. Greater emphasis should be placed by both Government and industry on upgrading and improving process technology, since productivity enhancement is largely dependent on increasingly efficient production processes. With respect to market share, defense industry firms should capitalize on sole source opportunities, but recognize that a demonstrated willingness to reduce costs even in the absence of competition will carry political weight influencing future sole source awards.

Experience curve theory for consumer and industrial products advocates capturing the growth in markets, rather than attempting to displace the market share of established producers. For defense industry firms, this is most easily done by becoming established as the initial (if possible, sole source) producer. However, there are also profit opportunities for capable producers who are not initial producers. The Government sometimes seeks to develop alternative sources for critical products to maintain flexibility, rather than to obtain immediate price competition. Production oriented firms in particular should seek out such second source opportunities, concentrating on adding to their assortment those products which are compatible with already developed and established process technology. The combination of process compatibility and initial lack of emphasis on price should allow them to overcome the experience advantage of the original source and prepare for future price-based competitions.

New products are introduced in the military market place for a variety of reasons: primarily to meet operational needs, but also to increase flexibility and to maintain innovative capabilities. For the Government to realize greater productivity gains, standardization should be increased, and design changes and new product introductions should be reduced. Defense industry firms should become thoroughly familiar with life cycle cost methodology (to include the use of price experience curves in projecting future prices), and should place increased emphasis on the expected life cycle cost advantages of proposed new products which they are marketing.

Perhaps the greatest opportunity for the Government to capitalize on experience curve theory lies in the area of procurement planning and negotiations. Prior to the initial production of new products, life cycle cost estimates should be developed (using experience curve theory to forecast future acquisition prices) for such alternative procurement approaches as no competition, competition for initial production only, and continuing competition (i.e., maintaining at least two sources). The approach which minimizes the expected life cycle cost to the Government should then be implemented, provided it does not unduly restrict industrial flexibility and innovative capability. Experience curve based price projections can also be of particular value in preparing for negotiations for follow-on procurements of established products. While being generally guided by such projections, both Government and industry negotiators will also need to be completely familiar with factors influencing experience realization, providing a basis for negotiation of variances from price projections. (This is not advocating conducting negotiations based solely on price projections, but rather introducing such considerations as an added dimension to negotiations.)

Shifting now to a focus on buyer-seller interactions, consider first Government interventions in production contracts. The extent of Government intervention in contractor decisions appears to be partly responsible for the relatively gradual rate of experience realization in military procurements. Productivity should increase if interventions are reduced; over-control is counterproductive. For instance, designs should be required to meet form, fit, and function standards, with the contractor being free to make changes to improve producibility (provided the standards are still met). Form, fit, and functional capabilities should not be changed once production specifications have been agreed upon, except for cases of overriding military urgency (e.g., "nice-to-have" but non-essential features should not be added). Producers can help themselves as well as the Government by identifying areas in which reduced Government intervention could increase productivity.

Producer risks are also unique in the defense market place. Through funding most research and development, providing or paying for specialized tools and test equipment, and in some cases providing plant facilities for contractor use, the Government seeks to minimize some of the risks to which contractors are subjected. However, other risks remain, most notably due to market uncertainties. Orders are placed at irregular intervals, and for varying and often unpredictable quantities. Due to changing military priorities and close Congressional control of funds, there is often uncertainty even as to whether or not there will be a next order. Uncertainties such as these confound a contractor's efforts to build, train, and maintain a stable, experienced work force. They also serve as a disincentive to investments in process improvements, resulting in lost opportunities for gains in experience. Extended multiple-year production plans, bearing tentative Congressional approval when appropriate, should be shared with prospective contractors. Delivery schedules should be developed in cooperation with producers to minimize workforce turbulence. Producers can again help themselves by identifying the risks and uncertainties which are of greatest

concern to them.

Incentives should be provided to encourage contractors to manage efficiencly, with emphasis on achievable rewards, not just on penalties. Reduced Government intervention will mean greater responsibilities for producers, which should be recognized in the incentive structure. Both the Government and producers should ensure that all personnel who could reasonably be expected to influence the distribution of incentives are at least aware of the incentive structure. In particular, they should understand the ways in which they, as individuals, can affect the distribution of incentives. (The experience effect does not guarantee that productivity gains will be realized. Productivity enhancements will only result when individuals have the incentive, as well as the ability and opportunity, to make them happen.)

Finally, the catch-all category of productivity inhibitors deserves further attention. Several have already been identified, including excessive Government interventions, market uncertainties, and lack of real incentives. As observed in the present research, various production parameters also affect costs and thus price. Productivity will benefit from improved (two-way) communications between producers and the Government, especially during the development of production plans. Opportunities for productivity increases abound, but aggressive management is needed to convert the opportunities into realized productivity gains.

The experience curve effect provides a powerful tool for use by both Government and industry in a variety of applications. It can help contractors increase profits, and at the same time help Government procurement decision makers in maximizing the return on their expenditures of taxpayers' dollars. While it is no panacea, it is will worth understanding and applying.

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A NEW COST PREDICTION METHODOLOGY -
THE MATURE INDUSTRY APPROACH

Dr. Joleroy Gauger, Boeing Aerospace Company

INTRODUCTION

Design-to-Cost and Life-Cycle-Cost requirements on new DoD programs have forced both the customer and the contractor to develop a better understanding of when and where costs are incurred.

Cost commitment and spending, however, do not occur simultaneously. Figure 1 compares the commitment and expenditure of funds for any program. Note that while the majority of life-cycle-costs have been committed by the end of the conceptual phase of a program, only a small portion of the expenditures have occurred.

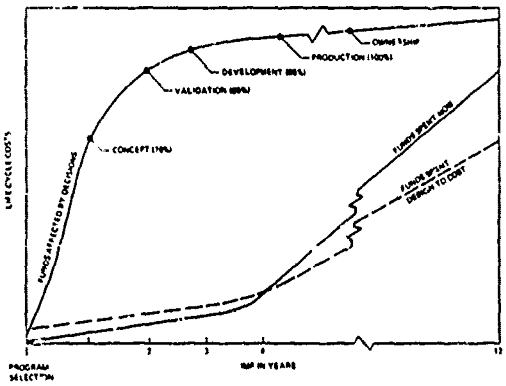


Figure 1 - Cost Commitment by Program Phase

The fact that the greatest cost leverage in a program exists at precisely that time when the least is known about potential costs forces the development of parametric cost models.

COST MODELING TECHNIQUES

Cost models are of two distinct types:

1) Parametric models which utilize variables (parameters) which have been determined as analytically related to costs

2) Accounting models which utilize a multitude of impact parameters which are the cost incurring elements of the program and are relatible in manhours, material dollars, tooling dollars, etc.

Figure 2 is an example of the variety of cost models developed within Boeing and illustrates types of models within program cost categories. Simulation is the imitative representation of the functioning of a system or process by means of another system; e.g., the computer simulation of a design or manufacturing process; or, at other levels within the cost model heirarchy, the simulation of a company, customer, program or economic system.

		PROCESS SIMULATION	COMPANY SIMULATION	CUSTOMER SIMULATION	LCC	ECONOMIC SYSTEM
ACQUISITION	RDT&E	SOFTWARE (WILL COST) FABRICATION * ASSEMBLY	AIRCRAFT ACQUISITION MODEL * MISSILE/ SPACE ACQUISITION MODEL *	NOT APPLICABLE		MATURE INDUSTRY • SOLAR CELLS • HIGH PRODUCTION RATE • LIKE INDUSTRY CHARACTERISTICS
	PRODUCT					
	DEPLOY/ INSTALL					
OWNERSHIP	OPERATE		PRODUCT O&S * "SHOULD COST" MODELS	SOFTWARE (WILL COST) USAF AIRCRAFT O&S MODEL COMMERCIAL O&S MODELS *	MOST DOC LCC MODELS LIE HERE	
	SUPPORT					
	SALVAGE					
TOTAL PROGRAM		TOP-DOWN SYNTHESIS (IN PROCESS)				AIRCRAFT-MARKETING MODELS * SOLAR POWER IMPACT

*PROPRIETARY MODELS

Figure 2 - A Hierarchy of Cost Models

Within Boeing, we have constructed cost prediction models for:

1) Software design/development
2) Structural fabrication
3) Structural assembly
4) Aircraft acquisition program
5) USAF aircraft O&S

and others.

Specifically, the others include a new cost prediction approach which arose out of the necessity to predict the production costs of the Solar Power Satellite.

THE SOLAR POWER SATELLITE CONCEPT

The Solar Power Satellite concept is an approach toward solution of the nation's energy problems which would utilize that non-depletable energy source one astronomical unit away.

Allow me to describe briefly the concept illustrated in Figure 3.

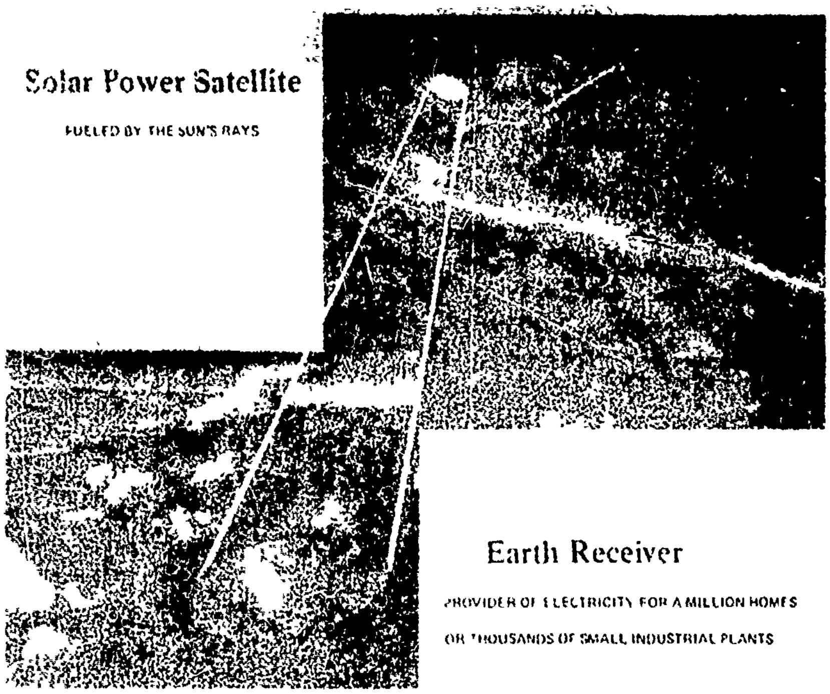


Figure 3 - Solar Power Satellite Concept

A unit of the Solar Power Satellite power system would consist of the satellite in geosynchronous orbit intercepting the solar radiation, converting that to electrical energy and then converting the low level electrical energy to microwaves which would then be transmitted to receiving stations on earth.

Two receiving stations per satellite would receive the microwaves and convert the microwave energy to electrical power compatible with existing transmission and distribution grids.

The overall efficiency from solar power intercepted to electrical power delivered to the grid will be $\sim$ 6 percent.

A few details now to illustrate the size of the system:

1) The size of the satellite - about 100 square kilometers.

2) The mass - about 100,000 metric tons.

3) The microwave transmitting array - 2 sets of about 100,000 klystrons each.

4) The solar cell array - about 15 billion solar cells.

5) The power delivered - 10 gigawatts - about 8 times the size of a typical nuclear power station.

6) The receiving arrays - about 10 kilometers in diameter.

The top work breakdown structure for the SPS program is as indicated in Figure 4. The total program sums from the three blocks at level 2:

1) The solar power system which consists of the satellite and ground receivers

2) The transportation systems consisting of several blocks at the next level

3) The space support and space construction systems.

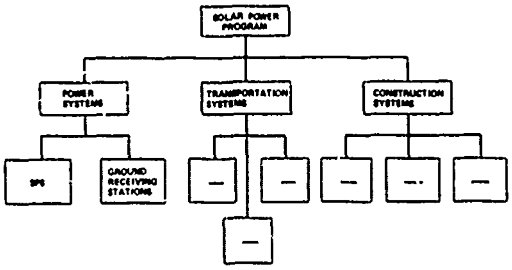


Figure 4 - Solar Power Program
Top Level WBS

COST PREDICTION PROBLEMS

We are describing a system which will deliver 10 gigawatts of power at a unit cost approaching 20 billion dollars for:

1) The satellite
2) Its assembly in space
3) The transportation costs to orbit
4) The ground receiver station costs.

What are the types of cost prediction problems?

1) Solar Cell Production Cost. The present production rate is under 2000 square meters per year. At the peak of the SPS planned scenario, the solar cell requirements would exceed 100 square kilometers of cells/satellite. Normally used extrapolation techniques (learning curves) are just not applicable.

2) High Production Rate Requirements. The development of a technique to carry one from existing production rates of 1-10/year for some items to the probable SPS requirements of 100,000 or so per year.

SOLAR CELL COST PREDICTION

Let's attack the problem of cost prediction for a solar cell market a hundred thousand times greater than the present market. The basic ingredient of a solar cell is monocrystal silicon - an element, essentially a basic metal.

The costs for cells at present are driven by the types of manufacturing processes used, the loss of finished monocrystal silicon during slicing, the power consumed in an inefficient process and the loss and waste of material and manpower.

Can problems like this be cured?

The answer is yes - however, it takes time and resources to do that job. The "mature" primary metals industries have solved similar problems in the past.

The market line for the primary metals industries relates the volume of metal produced to the total revenue for the industry. Figure 5 is a representation of the market for primary metals. The ordinate is expressed in terms of pounds/year moved through the industry. The abscissa is dollar volume for the industry (dollars/year).

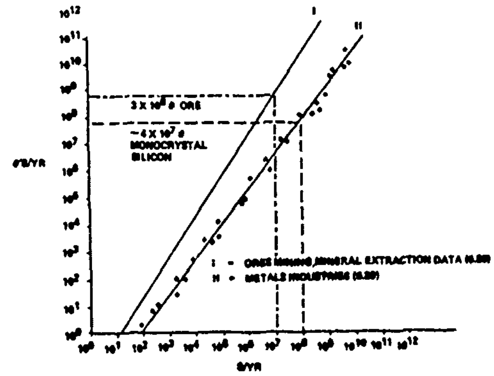


Figure 5 - Mature Industry (Metal, Ores)

Each point summarizes available data on the production and total revenue associated with, for instance, steel, beryllium, copper, etc. Twenty eight separate primary metals industries are represented here.

The equation for metals is V = AX+B

Where V is volume in pounds/year
and X is revenue in dollars/year

The correlation coefficient, $R^2 = 0.89$, indicates that the data are an excellent fit and suggests that "mature" industries involved in producing primary metals evolve along a market line which can be represented analytically.

Are solar cells any different?

No, they are not. Therefore, 100 square kilometers of solar cells will require ~ 40,000

tons of finished monocrystal silicon which will be produced for ~ 100 million dollars by a mature industry. If a value-added factor of 20 takes the metal to the finished product (a high value-added factor) then, the cost of solar cells produced by a mature industry in the 1990-2000 time period should be in the vicinity of 10-20 cents per watt.

Delphi predictions by the semiconductor industries lie in the range of 13 to 26 cents per watt.

The second line on this graph is a representation of the market line for ores and minerals - all the way from imported beryl (beryllium ore) at a few thousand pounds a year to sand and gravel at billions of tons per year. The correlation here is 0.80 - still a good fit - and another verification that volume and market value are related analytically.

HIGH PRODUCTION RATE EFFECTS

The next type of cost prediction problem faced on SPS, was the determination of the influence of production rate on production unit costs.

In the aerospace industry we typically have, for example, production rates from 1 or 2 per year to at most a few hundred units per year. Economic principals dictate the ratio of recurring to non-recurring funds.

For example, the lower the rate, the lower the early investment in tooling and facilities. Figure 6 illustrates the typical unit production improvement curve for an aircraft program.

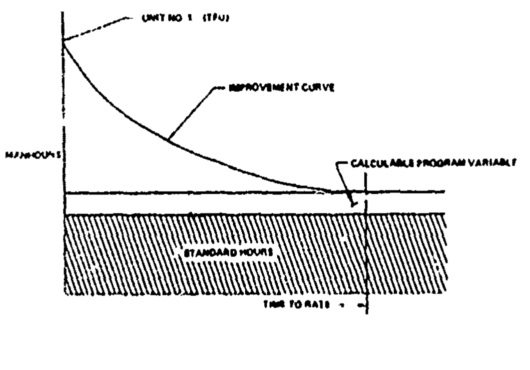


Figure 6 - Production Cost Baseline

By the thousandth unit, most of the non-productive elements under that improvement curve have been eliminated and the industry is producing efficiently, economically and profitably.

The bottom, hatch marked area is the "standard hour." Those hours which will be spent productively in producing an aircraft - those hours required to do the job for the designs produced.

The magnitude of the "standard hour" cost is dictated not only by design complexity, and customer requirements (specifications) but also by the amount of resources dedicated to the production process - tooling, facilities, etc.

Figure 7 illustrates that the resource dedication is related to the annual production rate. That is, the standard hour value is directly related to the annual production rate, and declines along approximately a 70% curve as one goes from typical aircraft rates to automobile production rates in vicinity of 10^6 - 10^7 units per year. Note: This <u>is not</u> a "learning curve."

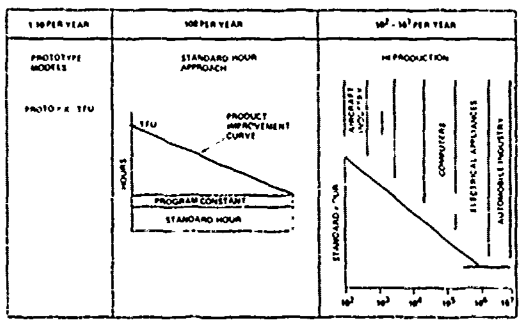


Figure 7 - Economic System Simulation - Mature Industries - Production Rate Effects

This <u>is</u> a production rate improvement curve and arises because of the willingness, as rates increase, to remove design and producibility problems by the early dedication of resources. This improvement arises purely because of the economics of the situation.

How can we use this information? A stepwise process:

1) We predict the "standard hour" for the system at typical operating rates.

2) Then we apply a 70% product improvement curve to determine the standards hours at the higher rate.

POTENTIAL IMPACT ON THE U.S. ECONOMIC SYSTEM

A major problem to be addressed is the determination of the impact on the economy that a project of this size will have.

We seek, therefore, answers to the following questions:

1) How big will the investment of industry and government have to be in order to handle a transportation job this large?

2) How big will the investment of industry and government have to be to develop the production capability required?

We have analyzed the relationship of "assets" to "revenue" for 25 or so classes of industry from aerospace to electrical utilities to grocery stores.

Table 1 is a list of those industry categories. The columns are:

1) Industry category
2) Number of industries considered/category
3) Range of assets within the category
4) Total assets of the industries in the category
5) Range of revenues within the category
6) Total revenues of the industries in the category
7) The relationship between assets and revenues
8) The correlation coefficient which indicates the validity of the original assumption.

These data were taken from Financial World, July 15, 1976, and represent companies in the top 500 profit making industries (mature) in the U.S.

The cumulative assets and revenues of the 319 companies represented here exceed 900 billion dollars, more than a third of the GNP.

TABLE 1

"LIKE INDUSTRY" CHARACTERISTICS - TOTAL ASSETS TO TOTAL REVENUE RELATIONSHIPS

CATEGORY	NUMBER	RANGE ASSETS	TOTAL ASSETS	RANGE REVENUES	TOTAL REV.	EQUATION	R^2
UTILITIES (CENTRAL)	27	524.3 - 6,534.2	52,893.1	196.5 - 1,908.2	17,229.7	R = 0.30A + 50.3	0.93
UTILITIES (EASTERN)	27	633.1 - 8,072.3	78,158.7	212.0 - 2,880.3	24,522.5	R = 0.31A + 15.1	0.88
UTILITIES (EASTERN)(1)	25	633.1 - 8,072.3	66,821.2	212.0 - 2,206.3	19,772.7	R = 0.26A + 100	0.965
UTILITIES (WESTERN)	11	715.4 - 7,419.8	23,270.6	143.8 - 2,646.7	7,212.0	R = 0.38A - 143	0.977
AEROSPACE (DIVERSIFIED)	12	340.7 - 2,894.6	18,768.8	493.1 - 5,166.3	33,021.8	R = 1.92A - 245.1	0.932
AGRIC. EQUIPMENT	4	1,114.3 - 3,574.8	9,887.5	1,519.3 - 5,488.1	12,912.9	R = 1.49A - 443	0.87
AIR TRANSPORT	5	1,151.6 - 1,894.6	7,529.6	963.8 - 2,037.1	8,633.2	R = 1.20A - 136	0.67
AIR TRANSPORT (2)	4	1,151.6 - 1,894.6	6,228.9	963.8 - 2,037.1	6,807.7	R = 1.53A - 748	0.956
ALUMINUM	4	2,180.9 - 3,569.5	11,182.5	1,851.9 - 2,924.4	9,516.8	R = 0.76A + 261	0.986
AUTO & TRUCK	5	1,048.3 - 24,342.8	50,083.9	1,473.3 - 47,181.1	95,483.4	R = 1.94A - 306	0.995
FOOD PROCESSING	26	151.7 - 2,128.9	25,582	212.5 - 5,288.6	53,050	R = 2.44A - 365	0 85
GROCERY STORES	6	509.6 - 1,709.0	5,560	2,115.8 - 10,442.5	28,379	R = 6.48A - 1277	0.92
OFFICE/COMPUTERS	10	442.8 - 17,723.3	34,023	539.2 - 16,304.3	32,405	R = 0.91A + 146.5	0.995
OILFIELD SERVICE EQUIP.	9	295.1 - 2,553.1	9,041	215.0 - 4,866.3	11,134	R = 1.70A - 467.6	0.869
PACKAGING/CONTAINERS	6	274.9 - 2,195.2	7,757.1	394.0 - 3,458.2	10,363.4	R = 1.24A + 120.4	0.909
PAPER/FOREST PROD.	19	152.7 - 3,681.7	26,062	146.7 - 3,540.6	27,831	R = 0.95A + 164.8	0.913
ELEC. EQUIPMENT	20	148.4 - 12,049.7	33,348	275.2 - 15,697.3	44,834	R = 1.278A + 110.6	0.994
ELECTRONICS	6	475.0 - 1,156.8	4,963	522.0 - 1,723.6	7,499	R = 1.374A + 113.4	0.823
MACHINERY (HEAVY)	18	191.5 - 3,893.9	18,149.6	169.9 - 5,042.3	24,625.2	R = 1.28A + 82	0.958
NATURAL GAS	25	298.1 - 7,179.0	41,061	379.2 - 6,423.4	29,442	R = 0.78A - 97.2	0.85
OIL (PETROLEUM)	35	368.0 - 36,331.3	190,924	99.1 - 48,631	232,021	R = 1.358A - 779	0.982
STEELS (INTEGRATED)	9	526.2 - 9,184.5	27,399	690.0 - 8,604.2	27,535	R = 0.946A + 180.2	0.984
TELECOM	12	589.7 - 87,036.9	129,125	161.9 - 32,815.6	50,820	R = 0.38A + 173.4	0.997

(1) Excludes Con Ed, Public Service
(2) Excludes Eastern Airlines
* Financial World, July 15, 1977

We have plotted the correlation coefficient, R^2, for a category against the number of industries in the category analysis (Figure 8).

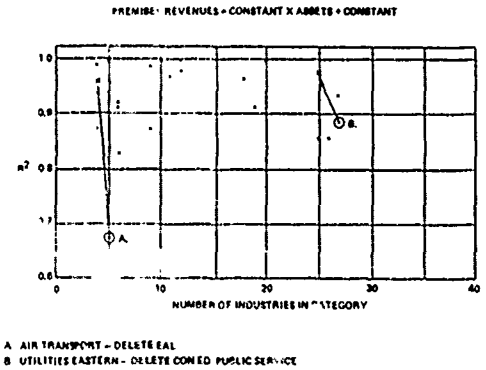


Figure 8 - Correlation Coefficient vs. Number of Industries in Category

With the exception of Point A, all correlations were in the range from 0.80 to 0.995.

Point A, with $R^2 = 0.67$, represents 5 airlines. If we exclude one data point (Eastern) the correlation between assets and revenues rises to $R^2 = .96$.

Is "Eastern" different?

The answer is yes. The value of the A-300 airbus fleet was not included in the asset statement for Eastern Airlines.

We have demonstrated the validity of the assumption that industries develop predictably - to survive and expand, money must be invested - increased assets are required to increase revenues.

Can this information be used?

Yes. An analytic expression which relates assets and revenues can be adapted to predict investment costs if one can begin to structure the other variable - revenue.

Let me illustrate the approach -

A PREDICTION OF INDUSTRY INVESTMENT TO SUPPORT SPS

To use the assets - revenue equation in attempting to size the impact of the SPS program on the economy, we must know:

1) The maximum production rate of satellites

2) The cost breakdown by:
   a) Satellite production cost
   b) Ground station production and installation costs
   c) Transportation costs to orbit
   d) Construction costs in space

For the examples to follow I have used a hypothetical number of 20 billion dollars per satellite at seven satellites/year with the cost categories as shown in Figure 9.

Economic impact

- What is the investment required by industry and government to assure economic maturity for this size program

Cost figures (example for calculations only)

1	Satellite production cost (1)	6000
2	Ground receiving station (2)	6000
3	Satellite transport costs	6000
4	Satellite – in space construction –	2000
	Total Unit Cost	20,000

Figure 9 - Scenario - SPS Rate Will Maximize at Seven Units per Year

The next step for each of the major categories is to establish the "nature" of the production job.

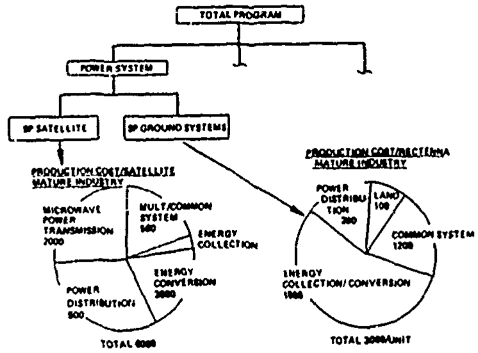
Figure 10 illustrates, for example, costs of:

500 million for the multiple/common systems on the satellite

3000 million for the solar cell blanket

500 million for the power distribution system

and 2000 million for the microwave transmission system.



*COST NUMBERS ARE ILLUSTRATIVE ONLY

Figure 10 - Satellite and Ground Systems Cost by Major WBS Elements

The third step in this exercise is for each major cost category (in this case, satellite production costs) to assign the cost breakdown by satellite WBS element by industry category in order to determine the amount of revenue (satellite cost) seen by each industry category. This is demonstrated in Table 2.

Table 2 - Satellite Systems, Production Cost by Industry Category per Satellite

SPS SYSTEMS	AEROSPACE	ELECTRONICS	ELEC MACHINERY	TOTAL
MULTIPLE/COMMON	300	180	20	500
ENERGY CONVERSION	300	2500	200	3000
POWER DISTRIBUTION	300	-	200	500
MICROWAVE TRANSMISSION	300	1400	300	2000
TOTAL	1200	4080	720	6000

* COST NUMBERS ARE ILLUSTRATIVE ONLY

For example, the energy conversion systems per satellite would provide revenues of:

300 million to aerospace category

2500 million to electronics industries

and 200 million to electrical machinery industries.

The last step in this particular exercise is to use the revenue generated per satellite for each industry category; multiply by the rate and obtain the total revenue flowing through each industry category/year due to the solar power program when peak rate has been reached. Using the "market line" equation of assets to revenue we can then calculate the asset buildup per industry category. Sum those and arrive, in this case, at a figure approaching 30 billion dollars. The results for this example are presented in Table 3.

Table 3 - Satellite - Revenue by Industry Category for Seven SPS/Year

INDUSTRY	REVENUE/ SATELLITE	REVENUE AT PEAK RATE	REVENUE/ASSET EQUATION	PREDICTED ASSETS
AEROSPACE	1200	8 400	R = 1.82A 246	4 603
ELECTRONICS	4080	28 560	R = 1.37A + 113	20 764
ELEC MACHINERY	720	5 040	R = 1.26A + 111	3 851
TOTALS	6000 PER SATELLITE	42,000 PER YEAR		29 118*

* FOR THE COST FIGURES USED IN THIS EXAMPLE, INDUSTRY WOULD DEVELOP ASSETS APPROACHING THIRTY BILLION TO SUPPORT THE PRODUCTION OF THE SOLAR POWER SATELLITE ALONE

A similar set of calculations for the ground systems is presented in Tables 4 and 5.

Table 4 - Ground Systems Production Cost by Industry Category

Rectenna (2/sat)	Aerospace	Electronics	Elec Machinery	Total
Land	—	—	—	200
Common	2000	400	—	2400
Energy Collection/ Conversion	1000	2000	—	3000
Power distribution	100	100	200	400
Total	3100	2500	200	6000

Table 5 - Ground Systems

Revenue by industry category for 7 SPS/year

Industry	Revenue per set	Revenue per year	Equation	Predicted assets
Aerospace	3100	21,700	R = 1.92A - 245	11,430
Electronics	2500	17,500	R = 1.37A + 113	12 691
Elec Machinery	200	1,400	R = 1.25A + 111	1,007
Totals	6000	40,600		25,128*

* For the cost figures used in this example, assets of 25 billion would be built up by industry to handle production jobs on the ground systems for SPS at peak rate

For this example, assets approaching 25 billion will be accumulated by industry to support the ground systems production.

The transportation costs per satellite will generate revenue for:

1) The aerospace industries (airframes)
2) The chemical industries (propellants)
3) The electronics industries (C^3)
4) Something akin to the airline industries (transportation operations)

The data is presented in Table 6.

Table 6 - Transportation Revenue
Earth - Leo - Geo

REVENUE BY INDUSTRY CATEGORY

CATEGORY	REV/SATELLITE	PEAK REV/YEAR	EQUATION	PREDICTED ASSETS
AEROSPACE (PRODUCTION)	2000	14,000	1.92A - 245	7419
CHEMICAL* INDUSTRY	1000	7 000	1.30A - 779	5720
ELECTRONICS	1000	7 000	1.37A & 113	5027
AIR TRANSPORT (SIMILAR)	2000	14 000	1.92A 743	[illegible]
TOTALS	6000/SATELLITE	42 000 YR		27 [illegible]**

** FOR THIS EXAMPLE, INDUSTRY WILL ACCUMULATE $28 BILLION IN ASSETS TO SUPPORT THE TRANSPORTATION ASPECTS OF SOLAR POWER PROGRAM

* PETROLEUM EQUATION

For each category we can then calculate the revenue/industry/year using the appropriate asset/revenue equation to predict assets approaching 28 billion dollars in support of the transportation tasks for SPS.

SELLING PRICE OF SPS POWER

Finally, let me take a cut at predicting the <u>selling price</u> of power derived from the assets/satellite, the availability to deliver power as a percent of total hours/year, and an equation which relates revenues to assets for the typical electrical utility:

First	- Assets/satellite @ 50% of cost	10 billion
Second	- Availability Operating hours	90% 7890/year
Third	- Kilowatt hours/ year	78.9 billion
Fourth	- Governing equation (utilities)	R = 0.30A+50
Fifth	- Revenue	3.050 billion

Finally- Cost/kilowatt hour = 3.87 cents/kw hr

CONCLUSION

While most of us are familiar with normal modes of cost prediction, e.g., learning curve extrapolations or even Delphi techniques, there exist problems in prediction which defy solution by "normal" means. In particular, when prediction problems arise which involve cost projections for systems which lie over the economic horizon, we must use methodologies which are consistent with the fraction of the economy involved and analytically derivable relationships which arise because of market factors. The mature industry approach is such a methodology.

MEASURING AND PREDICTING PRODUCTION DISRUPTION COSTS DUE TO DESIGN UNCERTAINTY AND DELIVERY URGENCY

E. B. Cochran, Management Consultant

1. SUMMARY

The disruption to cost and delivery often found in major DoD programs usually is the product of two factors. First, is the inherent uncertainty of development work. Second, such work is performed in the context of an urgent need to deliver production units to the military customer. The same factors also apply to the relatively less frequent disruptions of commercial products.

This paper describes the result of further researches into disruption along lines outlined in 1977 by a paper delivered to the Sixth DoD Acquisition Symposium [1]. One project pursued recently is the construction of an interactive computer model for the disruption process. The immediate goal was to predict disruption cost (in terms of production manhours) by quantifying their dependence on uncertainty in the development phase and the urgency of delivery dates. Several major benefits are gained by a successful effort: more realistic appraisal of the cost and delivery dates for a major program, both before go-ahead and during its conduct; improved time-cost tradeoff analysis; more effective early-warning of cost and delivery difficulties; and more objective appraisal of the facts which underlie contractual controversies involving disruption. An interesting result is that a model shows far greater ability to identify and measure disruption costs after they occur than is provided by any accounting system. The disruption process itself is thereby illuminated. The model also appears capable of improving the accuracy with which responsibility for cost overruns and delivery delays can be assigned.

Further refinements now under development will facilitate estimating the probable range of design delays and changes which may affect program performance. Presently, the model focuses on labor hours expended in a long-cycle operation producing at a relatively low rate, while its capacity for detailed analysis is somewhat limited by the medium-sized computer system employed to date. However, the principles and techniques used lend themselves to other production structures and to other cost aspects of disruption, such as labor rates, overhead and material. Substantial programming has also been done to develop capability to handle more intricate problems [6].

2. INTRODUCTION

The Domestic Environment

It is hardly news to state that neither the political leadership nor the taxpayers of this country are in a mood today to accept greater government expenses, no matter how justified. This attitude is compounded for defense expenditures, where technical complexities, long lead times and philosophical differences weaken the support of both citizen and politician.

Each national administration begins its career with clucking over what it considers the disgraceful overruns perpetrated by its predecessor. Every few years, therefore, we have a new round of pontification over the heroic steps to be taken in correcting the situation for all time. The current pressures are intensified by a number of unique factors. First is a milieu of social change and great political sensitivity to it. Second, reaction to Vietnam has not yet run its course, and our national leadership must respond to continuing antagonism toward needs expressed by the military. Third, there is a national realization that the inherent limits to growth are forcing the United States toward radical reallocation of resources and priorities. Fourth, is a lowered level of confidence in the judgement and pronouncements of public figures.

The DoD Challenge

In the midst of all this, the DoD grapples with a Brobdingnagian management task. It faces a highly determined, technically competent opponent which focuses vast and increasing resources consistently on its long-range imperialist objectives. In the last decade there has been serious decline in our military capabilities, both relatively and absolutely, and important erosion of NATO. Despite intense competition for every budget dollar from other governmental agencies, DoD must deal with an unparalleled rate of technological development which makes costly development programs a way of life. These often contain substantial technical and other risks, which may cause serious discrepancies between plans and results.

Recently, for example, there have been large Navy overruns and related bitter confrontations with contractors. The Navy is certainly not unique in this respect; there is no dearth of Air Force and Army experiences. But in the current domestic environment, it was perhaps inevitable that these Navy controversies would stimulate exceptionally strong political reaction. The direct effect of such arguments is serious enough: DoD suffers extended program delays; contractors cannot earn a decent return on their investment; valuable working relationships are eroded; while the overruns and delays themselves expand, since means of

dealing with these complex situations cannot be worked out in timely fashion. But there is more, for the credibility of all parties to the controversy is degraded, taxpayers feel frustrated and political leadership feels impelled to take "positive" action. And so now we hear that major long-range Navy programs are being deferred, cancelled or diluted. No one knows how far the effects of such reaction may go.

What are these monumental battles about? The outsider only sees that screams of "disruption" by contractors are matched with charges of "mismanagement" by the Navy. But such verbal boasting is merely the tip of a very large iceberg. The real problem is the failure of both sides to effectively understand the logic of procurement which involves substantial advance in technology. As a result, there are unrealistic expectations which, despite meticulous contractual provisions, make massive overruns and schedule delays inevitable and produce complicated disruption controversies which cost much time and money.

Source of the Problem

In my opinion, this lack of understanding - and communication - occurs for two reasons. First, the phenomenon of disruption itself is by far the most complex problem in managerial theory or practice, and one which is poorly understood in any general terms. Second, defense product development involves the most sophisticated technical environment possible; it is an area where little can be learned from procurement manuals and where predictions are fraught with peril. To list the primary questions which repeatedly surface in these arguments may help show the difficulties:

- What changes really occurred?
- Who was responsible?
- How did their implementation affect cost and delivery?
- Was the implementation timely and efficient?
- Were there other effects?
- What did they cost?
- Were good management practices used?

The questions seem simple. Actually, they raise profound issues. Many matters of fact arise which are difficult to define sharply. Complex calculations are needed which go far beyond the objective data available. Even to have a bare chance to find answers requires that the underlying development process itself be well understood by the parties at odds.

But the actual practice of disruption analysis shows little evidence of progress in understanding the basic issues. For example, when one reviews contractor methods for calculation of disruption claims, one is struck by their ad hoc nature, their lack of fundamental organizing principle, their inconsistency of approach from one case to the next, the use of arbitrary technique. One senses deep confusion in these sad but earnest attempts to explain what are very real and hurtful situations, and such confusion invites the procurement agencies to cut large swaths in the arguments. The agencies' negative responses may be in line with their responsibility, but they do little to clarify the realities of these complex situations. Meanwhile, the cloud of rhetoric continues to swell.

The question is often asked: why, with all these difficulties, don't we simply reduce the amount of overlap or concurrency between design and development? Why make something before it's designed, so to speak? Where would General Motors be if it built cars this way? A good question, and there is no doubt that the overlap should be at an absolute minimum. But there is another side to the coin. Time, too, is a resource, and DoD cannot always afford the luxury of a leisurely incremental development program. Further, even massive overruns may be cheap in comparison with the benefits from earlier delivery, many of them hard to quantify. C5A's, SRAM's and DD963's are not Chevrolets, nor even Cadillacs.

In short, concurrency will always play a part in DoD acquisition policy. The question is, how much of a part? To answer this requires a new approach.

A Modest Proposal

The time has come to recognize formally that urgent procurement contracts requiring new technology will always suffer what we now term "disruption". It may help to define that term: disruption costs are those which exceed the costs which are necessary under orderly and predictable conditions of design, development and entry into production. Merely to state this tells us that few significant new DoD programs will be free of disruption. The costs of disruption can easily run a quarter of those for an entire procurement cycle, and an even greater ratio for the pure development stage. That being so, we must establish realistic methods by which to <u>predict</u> their magnitude and <u>minimize</u> the effects when they occur.

This may sound suspiciously like just another call for better management procedures, a subject which has received much attention without permanent success. But it is not that at all. Rather, it calls for a different approach entirely, one which:

- Accepts the potential for cost overrun, though with intense effort to minimize it;
- Requires a realistic assessment of it; and
- Makes this philosophy workable by using specific methods to estimate delay and disruption effects.

The first two items of this proposal are founded on a theory of disruption presented at the Sixth Annual DoD Acquisition Research Symposium [1]. The third introduces a computer modeling procedure briefly described by the earlier paper, which now has been developed sufficiently to demonstrate the realism and accuracy of the approach. The crucial step is to focus attention on high-risk areas. This allows us to estimate the possible range of cost overrun and delivery slippage. Currently, the emphasis is on production delivery and labor hours. Related modeling procedures are being developed to allow better prediction of the pattern of design delays and changes, and effects on other production cost items.

Benefits and Cautions

There are four major benefits of this new philosophy. First, it encourages far more realistic consideration of a proposal to undertake a new program - since attention centers directly on the potential for delay and disruption. Second, the model itself can also estimate potential savings from relaxation of urgent delivery schedules or reduction of design risk, or the opposite. This lends realism both to the initial evaluation and to subsequent status reviews. Third, the model's ability to quickly translate design disruption into production cost and schedule effects permits the establishment of effective early warning procedures. This alone justifies careful consideration of the approach. Fourth, customer and contractor can jointly address the effects of design delays and changes, and of schedule revisions, in a far more objective manner. This should help to resolve questions concerning potential disruption effects before they expand to dominate the procurement relationship. Incidentally, the model should also be an unusually effective general estimating tool.

While the benefits are important, we must exercise some caution. First, we cannot expect instant results. The construction of a reasonable model for a major program takes time and money, even though modular interactive techniques were designed into the first major application. Eventually, of course, it may be feasible to have a family of such models on line, which may be adapted to a new proposal in a few days or weeks.

Second, once a program has been decided on, the funds related to the estimate of potential disruption costs should not be made easily available to the contractor. For they would then be simply considered part of the normal budget and spent as a matter of course. There would effectively be little or no provision for the unplanned costs which might well develop later. Obviously, there should be no reduction in the efforts to minimize disruption by good management, development incrementalism or otherwise. To recognize the probability of disruption in a given case cannot be considered a license to spend the money.

3. DESIGNING THE MODEL

We shall begin with a brief look at an idealized version of the labor hour pattern typical of disrupted production. Exhibit 1 shows such a pattern, developed in 1959 by the author, which he dubbed the "S-curve" [2]. The baseline for this example is an ordinary improvement curve of 85 percent slope, while the bulged area above it represents costs due to disruption. The size of the bulge varies according to what may be broadly termed "leadtime" or "phase overlap" conditions.

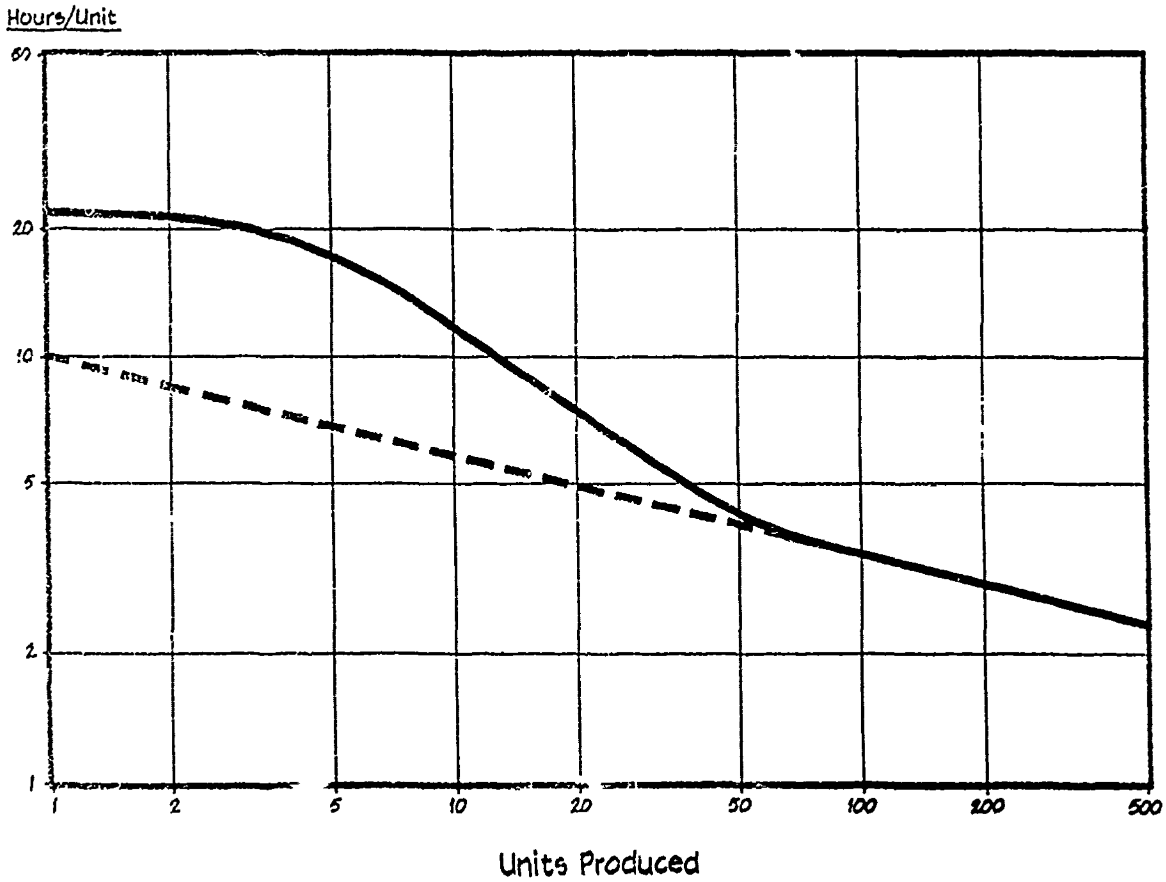
Now the disruption mechanism is extraordinarily complex. It originates with production delays and task changes, and evolves through the interrelationship of drawings, production processes and vendor activities. The overall effect may be inferred from comparison of actual hours with a suitable benchmark or "should-cost", but the details simply cannot be measured directly by any accounting system. So, as a first approach, we might examine the leadtime conditions for a specific case. We may then estimate their effect on hours by comparison with experience on other programs [3: 155-200]. Interactive computer programs have been developed to facilitate this estimating procedure.

When the necessary data is available, the procedure is rapid, inexpensive and reasonably accurate. Unfortunately, data is usually hard to come by or the conditions of a new program may differ widely from prior experience. It is therefore useful to develop a method which does not depend on such specialized records and which is more adaptable to new conditions. This requires detailed calculations which focus on the more significant events - actual or forecasted as appropriate - and attaches costs to them which reasonably replicate their effects on operations. Such an approach is far too complex for any but a computer modeling procedure.

EXHIBIT 1

THE BASIC S-CURVE PATTERN

85% Slope



The model itself is developed on an interactive computer program which allows the user to enter appropriate design, production and schedule characteristics under careful scrutiny, Exhibit 2 provides a brief flow chart, to aid in explaining the procedure. In view of the shape of the disruption labor cost pattern, the model is sometimes termed an "S-curve" model.

Basic Provisions

The first step is to describe the production process. This incorporates the usual predecessor-successor relationships found in PERT networks, but also allows for considerably more sophisticated relationships between the states of completion of any two or more basic activities. Exhibit 3 diagrams the situation for the model being presented here. For each unit there are ten major workcenters, each subject to several constraints. In total, for all units covered by this analysis there were over 500 constraints.

The second step calls for parameters of the production facility itself, including its resource capacities and growth rates: manpower by skill, facilities, storage space, etc. These parameters also constitute significant constraints on facility capacity to deliver units, and pressure on them generates cost penalties.

Third, characteristics of the product's cost are entered for each workcenter, such as their basic cost level, optimum crew size and improvement slope. Reliable estimates of the basic or "should-cost" must be used, since they affect the interface between the production process and the facility's limits. After considerable experience with parametric estimating techniques [5], I feel they are very helpful in establishing the model's should-cost data, provided the results are properly matched to the facility in which they will be applied. This phase of model development is crucial in getting accurate results, and may require extensive study if suitable data is not immediately available. It is also important to consider the degree to which the usual cost estimating procedure incorporates factors which will also be measured by the cost penalty factors discussed below. The modeling method reveals - perhaps for the first time - the degree to which ordinary cost judgements are affected by such factors.

Fourth, the master schedule of deliveries is entered, together with appropriate "drop dead" dates. Using the network pattern, cost characteristics and design delays, the program translates the master schedule into subordinate schedules for the various components. This data will be of great importance in determining the amount of "crashing" required to meet schedules, and the associated cost penalties.

Fifth is data on the direct effects of design uncertainty. As one item, delays in start dates for major tasks may be entered, together with expected times to develop the necessary drawings. The model will then determine the earliest possible start and complete dates. In turn, those dates are compared with master schedule requirements to define the degree of production delay. Another group of entries concerns the timing and magnitude of design changes, with their effects on lost learning, on rework and retrofit activities and on unchanged work (both on the immediate task and on others). There is also the matter of general design "turbulence", which produces significant rolling obsolescence without necessarily causing noticeable growth.

Sixth, two characteristics of the labor force are required. One is the quantity of each skill available in the company and in the community. Those in the company must further be described in terms of their seniority structure, and both groups in terms of their skill level, or the amounts of training needed. The second describes the headcount shrinkage for each seniority layer of personnel as it continues employment over time. Such shrinkage can have enormous effect on the disruption costs to be computed later, and care should be taken in developing this data.

Cost Penalty Functions

A number of cost penalty functions are essential to achieving the purpose of this model. These reflect the situations which develop during production under disrupted conditions, and during periods of startup and phaseout of operations. The model uses them to estimate the cost effects of those abnormalities. The most important items are very briefly summarized below.

Reductions in flow time are often initiated to compensate for design delays or unexpectedly long flow times in predecessor activities. This may produce over-staffing with several types of inefficiency resulting. Multiple crews (second line or shift, etc.) will further reduce efficiency by diluting the learning curve. At the same time, design delays or bottlenecks elsewhere may require a slowdown of work in a given workcenter. This, too, will create inefficiencies of several types. Important inefficiencies are generated by the need to train each group of people newly introduced into the labor force, both during the manpower buildup phase and as a

EXHIBIT 2

LABOR DISRUPTION MODEL

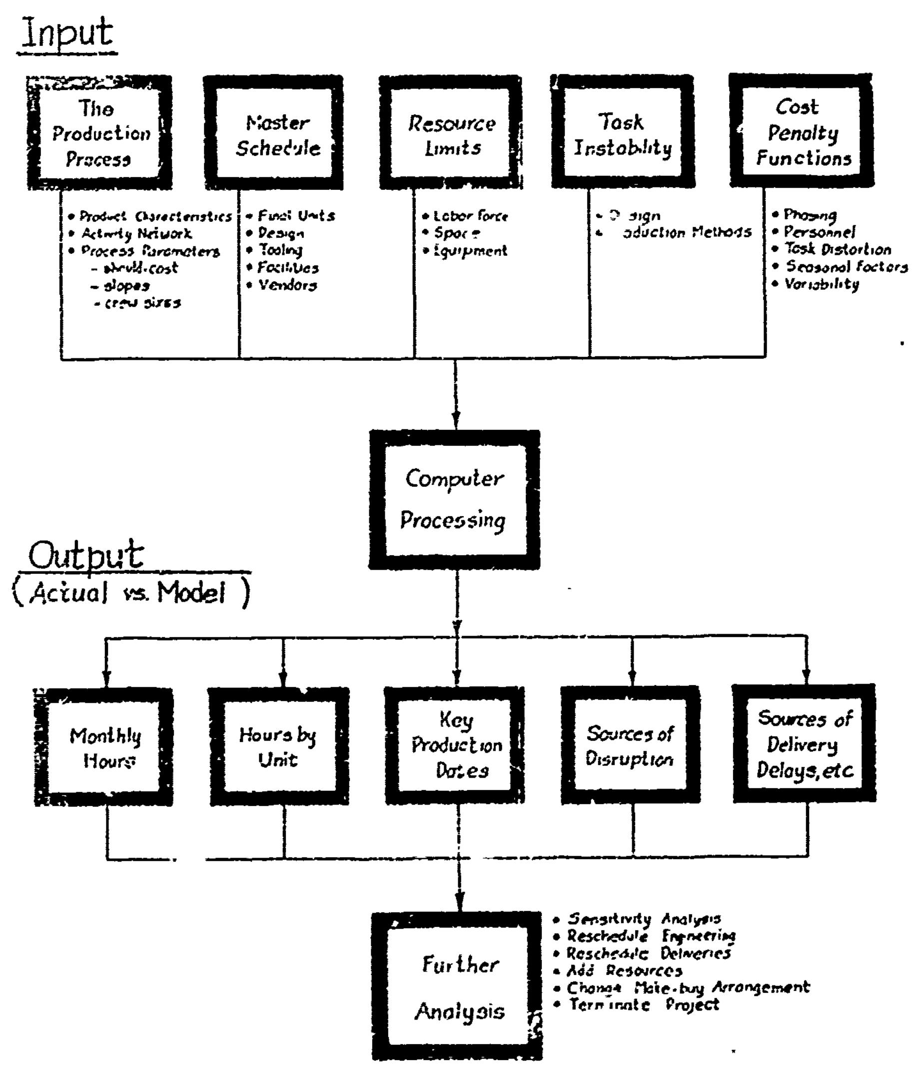
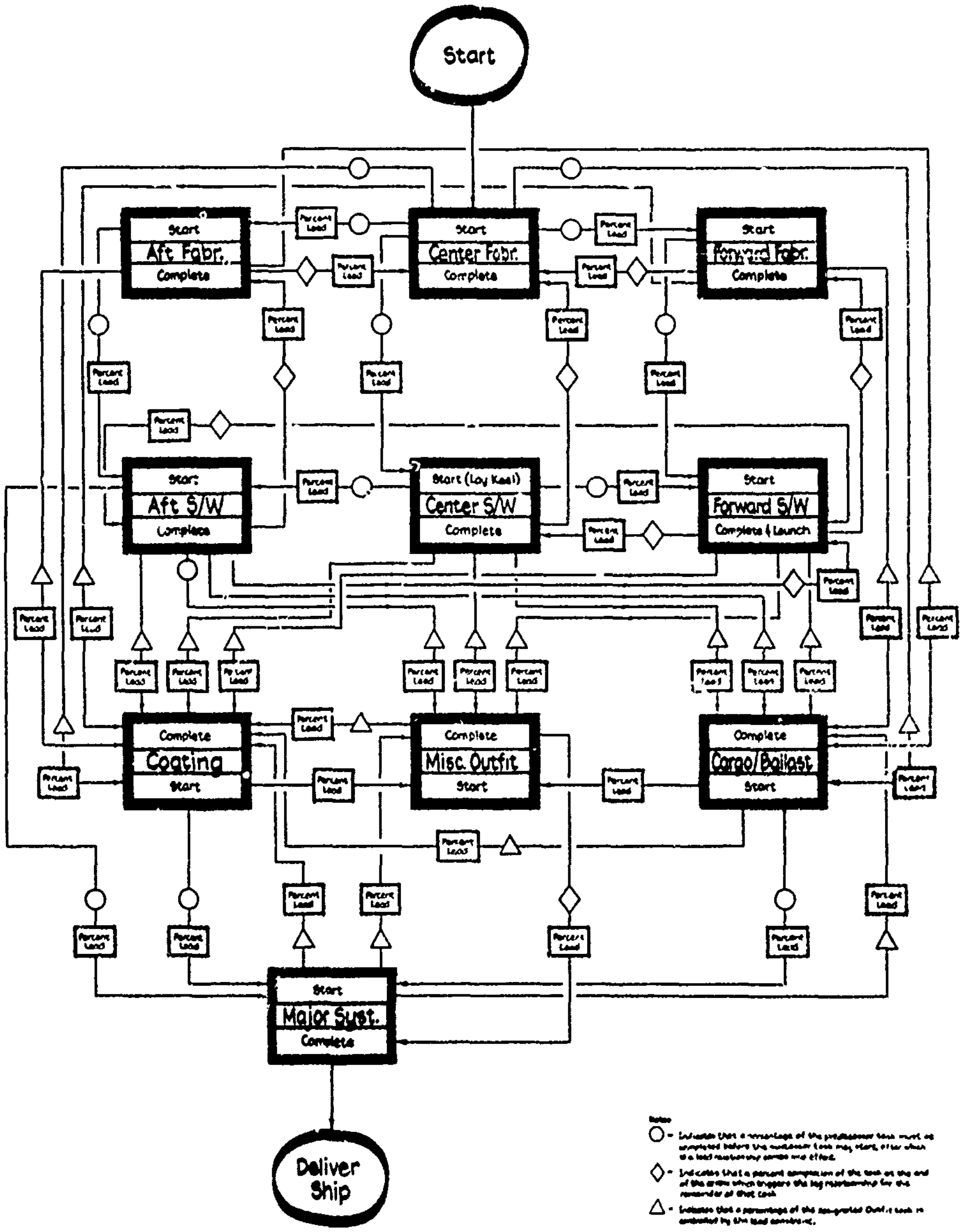


EXHIBIT 3

AS-BUILT TASK CONSTRAINTS



result of turnover. Seasonal factors may play a part when work is done outside or when it affects the availability of new personnel or the turnover of existing staff.

Many of these events may also create unplanned interferences between crews and semi-finished work due to space limitations, and require sequence changes and general discombobulation of orderly procedure.

What we term "phasing" effects are of great importance. Of relatively small impact under well-controlled conditions, they can climb to substantial proportions when design uncertainty and delivery urgency exercise their opposing pressures. Startup costs are, of course, at the front end. They may add from five to twenty percent to basic labor hours for early production, depending on the circumstances. Startup is sometimes estimated by use of improvement curves,but actually must be added to whatever basic cost level is established. Phaseout costs, often called "tailup", have long been recognized by a number of industries. Any thoughtful consideration reveals its considerable complexity [4], as it varies with the prospects of other assignments for the workmen, the rate of labor reduction (which may cause bumping and reassignment), and the effect of low output levels which generate inefficient use of tooling and facilities.

Erratic workloads result from design changes and delays and their ripple effects, as well as from other disruptive events. This requires managers to keep people that are not being fully utilized, in anticipation of peaks which lie just ahead. Lastly, important anticipation, carryover and compounding effects can develop from all these situations.

While the penalty functions are mathematical in format, for each one the user need only enter a simple percent penalty for a specific case. Such decisions should, of course, incorporate all the experience available. However, obtaining reliable detailed measurements of disruption costs is a practical impossibility. Thus, the effect of these functions heavily depends upon the judgement of experienced managers and estimators.

If this gives pause, recall that the only estimate not heavily based on judgements are those prepared for new lots of a firm design currently in production. This is a trivial estimating problem. Any estimate of real importance requires substantial judgement. The broad judgements normally used to prepare a major product plan grossly understate the cost impact of design uncertainty and schedule compression. An important reason is that such judgements do not separate two distinctly different types of event: first, the impact of design uncertainty on production startup; second, the precise manner in which these effects generate extra labor hours. This modeling method explicitly makes such distinctions.

The ultimate test of a given model lies in its ability to reproduce many complex events in a convincingly realistic manner. As we shall see, this model meets that test. There is every reason to anticipate a similar result for other applications.

4. OUTPUT OF THE MODEL

The program will now develop an estimate of program labor hours. Relevant time-phased comparisons between projected and budgeted (or actual) hours are made. The differences are identified with the various sources and types of disruption as computed by the model.

The analyst may then adjust the model parameters, to play "what if" games. Using the program's interactive features, he can explore such questions as the cost effect of various design delays, production acceleration rates, design change policies, major make-buy decisions, etc. He may also examine the effect of different cost functions for specific types of disruptive events. Upon command, the model's results may be displayed in the form of colored charts on a CRT terminal. This further facilitates prompt evaluation of the model's predictions and modification of scheduling and production policies.

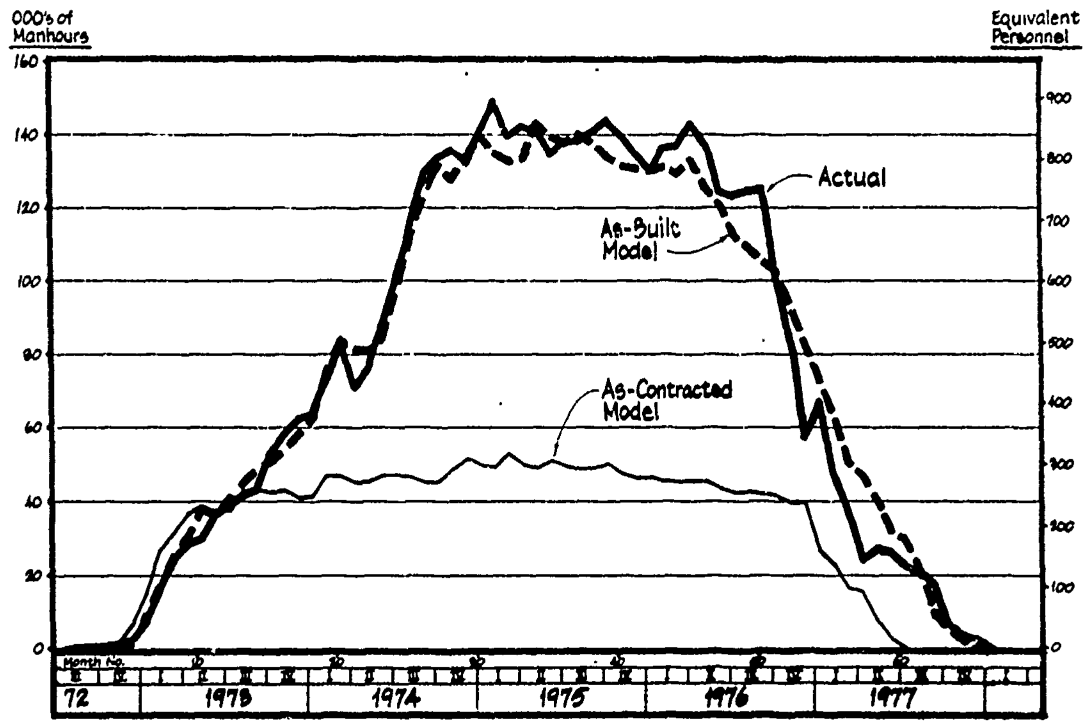
In summary, the model matched actual results very closely, both in total and in considerable detail. Exhibit 4 shows results on a monthly basis; the model projected monthly values to within an average of seven percent. The performance was a bit worse in later months, where data on changes and delays was also a bit weaker. Performance on a task basis is indicated by Exhibit 5. This shows each of the five large units involved, with the work segregated into the two main types - structural and non-structural. Again, the agreement is excellent, and that continues to be so as we delve deeper. Naturally there is some widening of the difference between calculated and actual hours as we go to smaller segments of the program.

This close agreement is even more impressive when we apply the model to the circumstances of the contract. With a substantially lower design cost and a much tighter production cycle, the model was still able to match the estimated should-cost very closely. In quantitative terms, the model separately replicated as-built and as-contracted costs which were in the ratio of 2.5 to one. There were also numerous confirmations of the as-built model's accuracy from other studies, and further support from

EXHIBIT 4

TOTAL PROGRAM HOURS

Actual vs. S-Curve Model

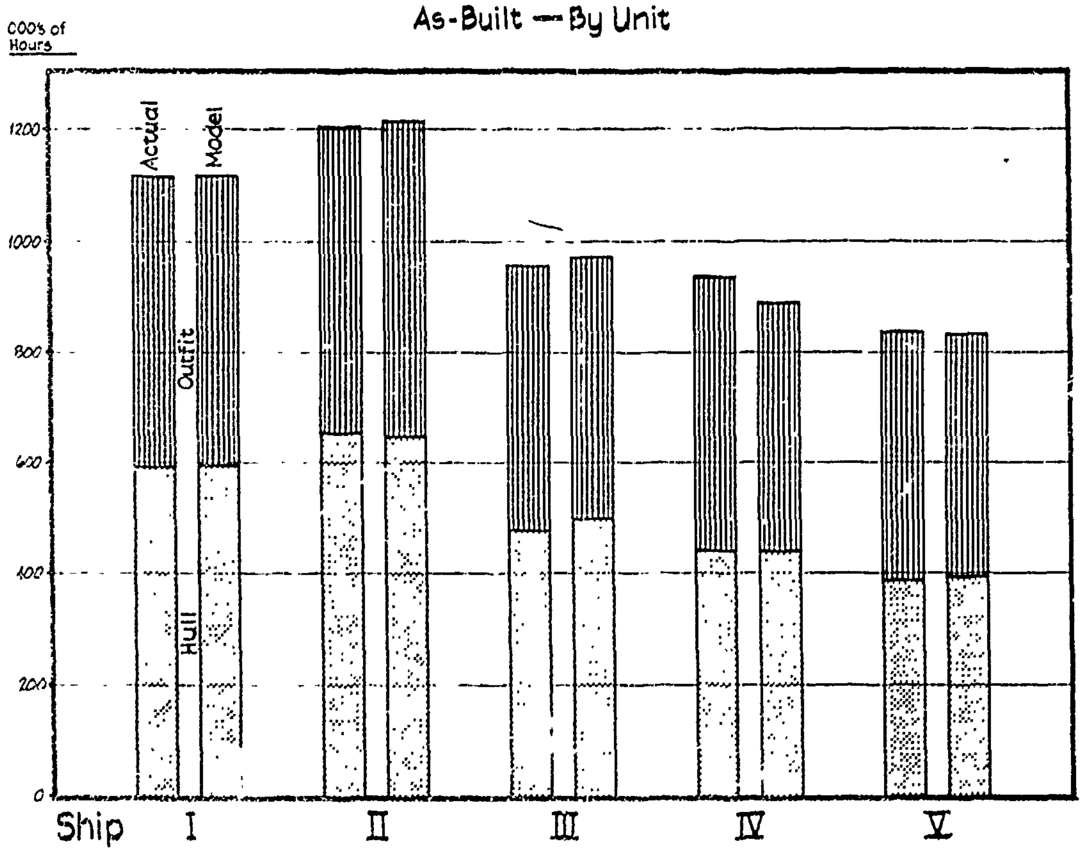


Level months.

EXHIBIT 5

ACTUAL VS. S-CURVE MODEL

As-Built — By Unit



the agreement with actual and as-contracted workflow statistics.

Estimated disruption hours amounted to some forty percent of actual hours incurred on this program. Their distribution by type was as follows:

Phasing	1 %
Change Effects	30
Personnel	24
Task Distortion	9
Task and Crew Variability	13
Interaction	23
	100 %

The phasing item represents the degree to which the model's tailup calculation exceeded the should-cost allowance. Change effects represent the loss of learning due to design and methods changes, plus the impact on methods and crew assignment, ripout and retrofit costs and the effect of changes on unchanged work. All are computed by the model in great detail following estimated parameters provided to it. Personnel disruption represents excess hours for training, crowding of crafts and the cumulative effect of over-manning on the rate of learning for specific tasks. Distortion comprises the effect on current efficiency of compression or stretchout of tasks. Variability measures the effect of rapid fluctuations in task workloads and in the demands made of the various crafts; these require the plant to maintain personnel levels above those strictly required for the work at hand. The interaction category is the result of a month-by-month and task-by-task computation of disruption compounding and carryforward effects.

These effects were studied on a unit-by-unit basis as shown by Exhibit 6. Again, the results are generally reasonable in relation to the facts of this case.

5. CONCLUSION

While we have not yet employed the model for this purpose, it seems logical that it would prove helpful in determining the responsibility for disruption costs. This murky and delicate subject is sometimes addressed by critical-path analysis. But CPM techniques focus entirely on time and fail to consider either the effect of resource constraints or the multiple and interactive consequences of a disruptive event. Since this modeling technique gives a more realistic representation of events, it should produce far better evaluations of responsibility for disruption costs.

Further Extension of the Model

Our approach may be extended to incorporate the network of key design, test, tooling, facility and procurement activities which precede the start of production. This will allow specific analysis of the potential for design delays in selected high-risk areas, as well as the possible effect of alternative development paths. Using a stochastic approach, we could estimte the probability of specific production slippages due to design delays and changes arising from the uncertainty inherent in the new technology of a given program. The remainder of the model will then estimate the corresponding cost effect. Such a capability is now under development.

Development of similar models for varying types of production processes offers no special difficulty. It does, of course, require the analyst to develop the network structure and data on capacities, basic costs, etc., and to adapt the penalty functions to the new situation. Such work is facilitated by the interactive procedures provided by the computer program.

Further modification to include overtime premium and escalation of labor rates is relatively simple. Expansion to reflect overhead and material costs is certainly feasible, but could get very complex if it were to entail the construction of a detailed model of the company's organization structure or vendor relationships. We have done financial modeling work which has considerable application here, but our thoughts concerning the degree of detail required are still being formulated.

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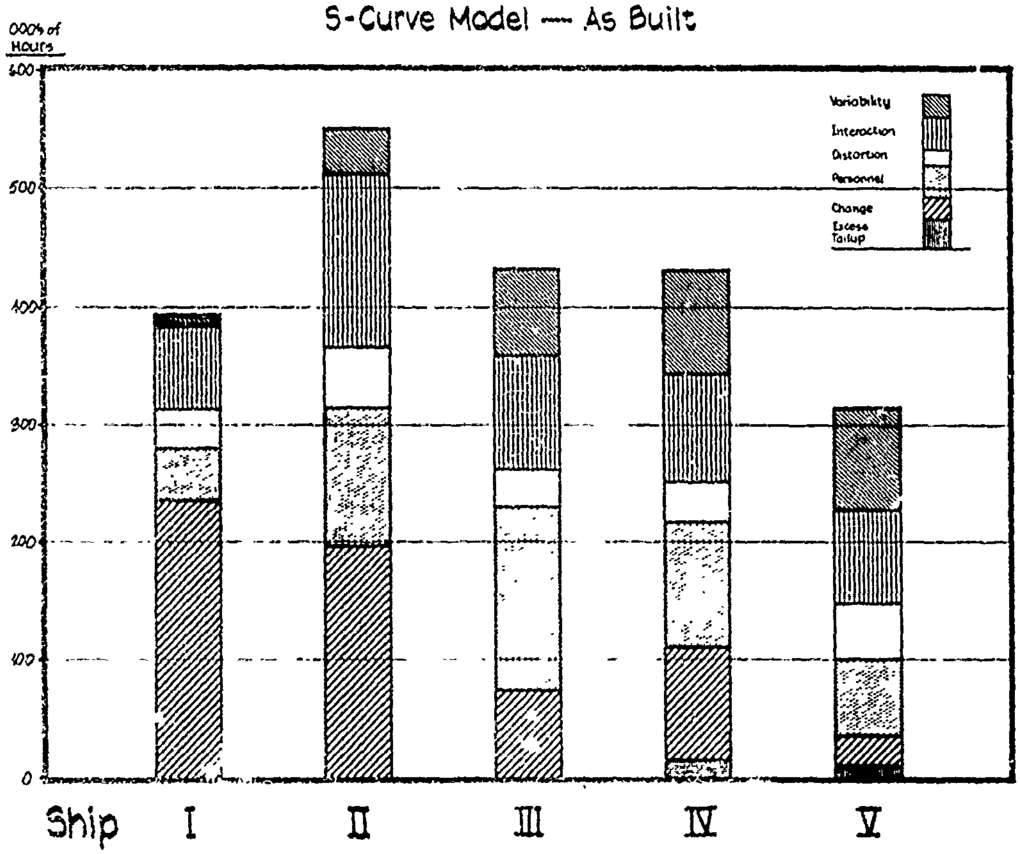
EXHIBIT 6

SOURCES OF DISRUPTION

S-Curve Model — As Built



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AN INVESTIGATION OF CHANGES IN DIRECT LABOR REQUIREMENTS RESULTING FROM CHANGES IN AIRFRAME PRODUCTION RATE

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INTRODUCTION

Ongoing airframe production programs sometimes experience a required change in production rate due to program stretchouts or accelerations. These rate changes are occasioned by such actions as budget changes, requirements changes or cost growth. For example if cost growth occurs, the planned annual funds expenditure will be exceeded. To prevent exceeding annual budget limits, production is stretched out so fewer airframes are produced in the budget year. If changes in airframe production rate cause important changes in unit cost, there is a need to be able to assess this cost impact so that an equitable contract adjustment can be made.

In an earlier paper [1], the results of research into the impact of a production rate change on the direct labor portion of airframe production cost was reported [2]. An extension of the learning curve approach was used to examine empirical data from F-4, F-102 and KC-135 airframe production programs. The approach included cumulative airframes and production rate as independent variables and direct labor hours per Defense Contractor Planning Report (DCPR) pound as the dependent variable.

It was found that the production rate explained a small but important amount of the variation in the direct labor requirements. Furthermore, the extended approach, with both cumulative production and production rate as drivers, predicted direct labor requirements better than the standard learning approach with only cumulative production as a driver.

In 1977, Congleton and Kinton, with the author as an advisor, replicated the research summarized above. Product data from F-5/T-38 airframes were used to test the procedures. This paper describes some of their findings which essentially validate the original work [3]. First, a description of the research is advanced. Then findings, conclusions and some observations are presented.

THE THEORY AND THE RESEARCH

That the production rate is an important determinant of cost is an intuitive observation. It follows from our industrial revolution heritage of higher productivity as labor is divided. That a change in the production rate will produce a change in the direct labor requirements follows from the first observation. One would expect an exogeneous production rate increase to decrease direct labor hour requirement for a number of reasons. One is that a higher rate of production should allow for further assembly specialization thus avoiding time lost in switching from one task to another. A second reason is that a higher production rate should allow the spreading of batch fabrication set-up charges over a larger number of units. If higher rates lead to lower costs, one might also expect that lower rates of production would cause an increase in the direct labor requirements to produce airframes.

In airframe manufacture, the production rate can be expressed in a number of ways. One method used in the study was to divide the number of airframes in a production lot by the time span over which airframes were delivered for that lot. Thus the researcher needed only the lot size and the aircraft acceptance dates to calculate the delivery rate proxy.

Given a method for expressing the production rate, one needs to incorporate this variable into a procedure for evaluating and predicting its impact on direct labor requirements. The works of Orsini [4:71] and Noah [5:41] suggested that the production rate could logically be combined with cumulative production in a multiplicative model of the form $y = Ax_1^B x_2^C$ where: the dependent variable y represents some direct cost indicator such as direct assembly hours per DCPR pound for a particular lot of airframes, the independent variable x_1 represents cumulative airframes produced and the independent variable x_2 is some proxy for the production rate. A, B, and C represent coefficients in the model. This model is simply an extension of the standard learning curve model, $y = Ax^B$. The multiplicative model described above was used in the original and the replicated research efforts.

The data for replication of the original effort were from the F-5/T-38 airframe production program. The data were stratified by fabrication, assembly and total manufacturing categories as well as the different models that were produced. The researchers examined 15 different combinations of the data by regression analysis in order to evaluate the ability of the procedure to explain variation in the dependent variable. A sample data set is included in Table 1

TABLE 1

SAMPLE DATA SET

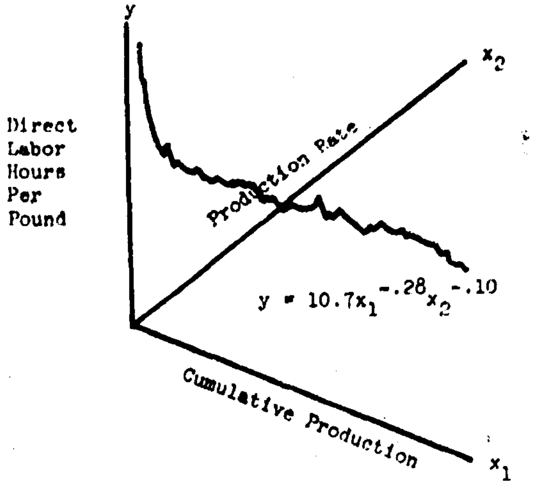
CASE (LOT)	ASSEMBLY HOURS PER DCPR POUND y	CUMULATIVE PRODUCTION PLOT POINT x_1	AVERAGE MONTHLY DELIVERY RATE x_2
16	1.85	382.0	13.5
17	1.82	432.0	24.0
18	1.79	502.0	33.3
--	--	--	--
--	--	--	--
--	--	--	--
55	0.76	4495.0	16.4
56	0.74	4558.5	17.2
57	0.75	4701.0	12.6

In addition to examining the explanatory ability of the procedure, the researchers also looked at its predictive ability. This was accomplished by truncating the most recent year's data from each data combination or data set. After developing model coefficients for the remaining data through regression analysis, the known but unused data that had been truncated were predicted. The forecasts and the actuals were then compared as a measure of accuracy. This technique was used for both the standard learning curve procedure and the expanded procedure to add a dimension to the comparison.

FINDINGS AND CONCLUSIONS

The study confirmed that the production rate is an important variable in explaining variation in airframe direct labor hour requirements. Although less powerful than the cumulative airframe variable (learning curve independent variable) the production rate variable was found to be statistically significant for all combinations of the test data. These include fabrication and assembly as well as total direct manufacturing labor hours per DCPR pound [3:92].

The concept of the procedure can be depicted as in Figure 1, a graphical representation of one data set. The downward slope of the curve reflects the decreasing cost relationship of the standard learning curve while the perturbations in the curve reflect the "fine tuning" effect of changing production rate between individual lots of production. The "B" coefficient is relatively larger than the "C" coefficient. This reflects the greater strength of cumulative learning as compared to the production rate as drivers in the model.



GRAPHICAL REPRESENTATION OF ONE DATA SET

FIGURE 1

As anticipated from the theory, the procedure predicts that an exogeneous increase in the production rate will result in a direct labor requirement decrease. A corresponding production rate decrease will predict a labor increase. There was no confirmation that the approach was better for one of the three data set stratifications, fabrication, assembly or total hours. In fact, the statistics gave mixed results indicating the approach was better for fabrication hours on one program and better for assembly hours on another [3:94].

The predictive ability of the expanded model was substantially better than the standard learning curve model in the vast majority of the situations tested [3:95]. Not only were the predictions better, they were more stable over increasingly wider time spans.

The original observation that one should not try to formulate a generalized cost model using coefficients obtained from various production programs was validated [3:96]. Even within the F-5/T-38 test data, the regression coefficients changed within a given test situation as successive cases were omitted from the test data in the predictive ability tests.

The proxy for production rate sometimes gave discontinuous data. That is, one lot rate might be 37.2 aircraft per month while the next might drop to 27 per month because of anomalies in the data. Such an anomaly might be produced by a delay in accepting an aircraft for a minor deficiency. If one had access to the final planned shop production

rate, it might be a better production rate proxy than the one studied.

It is concluded that the expanded approach to predicting airframe direct labor requirements is superior to the standard learning curve. It is particularly well suited to predicting the effects of a required change in the rate of production in an ongoing airframe production program. One would most likely use it in checking the reasonableness of an estimate arrived at by more conventional methods such as detailed estimating.

It ould seem worthwhile for airframe program managers to collect the necessary production data t‹ s ›p‹.' using the approach if needed. Cost growth and the frequently accompanying production stretchouts are commonplace and the ready availability of the needed data would facilitate the resulting need to price contract modifications.

Finally, it seems reasonable that the expanded approach would be useful on other programs where learning curve approaches have been successful. Accordingly, missile airframes, avionics and engine programs are likely candidates for further study.

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LEARNING CURVES, PRODUCTION RATE, AND PROGRAM COSTS: AN ILLUSTRATION OF RESULTS

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ABSTRACT

Economic Models of the production to order problem frequently conclude that the size of the order and production rate each influence unit costs. Despite this fact, the empirical work on aircraft costs credits production rate with little, if any, explanatory ability. These conflicting facts are resolved in this paper by use of a model which permits production rate to be a decision variable in the contractor's production planning. We derive an optimal production plan which requires production rate to change throughout the life of the program. We then contrast the planning situation where alternative order sizes are considered, with the production situation where unit costs are related to cumulative output given a production plan. This approach provides guidance for the use of data on past programs in the evaluation of future production plans. It also provides an explanation of the impact of program stretchouts on costs.

INTRODUCTION AND BACKGROUND

A usual intermediate product of production theory is the cost function. The cost function relates dollar cost of production to the quantity of output produced per unit of time, and in some cases, prices of resources used in the production process. The form of the cost function depends on the underlying production function and the competitive conditions in each of the resource markets. Its form also depends on constraints imposed on the firm's production decision. Cost functions derived from circumstances where one or more resources are fixed in quantity are labeled short run functions while those applicable to situations when all resources are variable are referred to as long run functions.

While the length of the time period involved is frequently implicit, the cost function is a flow concept relating the time rate of cost to the time rate of output. As such, its relation to various stock concepts like the quantity of capital equipment, the cumulative number of items to be produced (volume), and work experience of the organization at any point in time is difficult to specify. These stock concepts are frequently ignored in classroom treatments of the subject and in many attempts at empirical estimation of the cost function. This simplification is sometimes justified if the firm is in a steady state situation where demand rate is expected to continue indefinitely. Hirshleifer [4, 236-237] has argued that the simplification is consistent as well with the situation in which volume is expected to be proportionate to production rate. Nevertheless, explicit consideration of these stock concepts is of crucial importance in many industrial settings.

The stock concepts are so important in fact, that in some industries variations in costs are explained totally by stock changes, ignoring the flow concepts explicitly treated by economic theory. For example, the learning curves or progress functions developed to describe costs in the aircraft industry typically relate costs to number of items produced without any explicit reference to production rate or rate of usage of resources.

Attempts to integrate these two methods of describing variations in costs of production, learning curves and cost functions, have met with only limited success. Alchian [1] and Hirshleifer [4] have discussed some of the issues involved and have provided some intuitive expectations about the form of the resulting relation. Alchian states nine propositions on the variations of program costs due to changes in production rate, volume, the time horizon and the firm's production experience. Hirshleifer extends this work and relates it to more traditional cost theory. However, both works stop short of relating variations in costs to production in ways that are explicit enough for empirical estimation. Preston and Keachie [10] also relate learning to cost functions, but their graphical analysis of the situation also lacks precision. Oi [9] goes somewhat further. He purports to derive the nine characteristics that Alchian proclaims from an intertemporal production functions. His treatment is general and shows a potential explanation for learning in terms of standard production theory, but it too fails to specify the relations precisely enough for empirical investigation.

Washburn [12] addresses these issues directly. He formulates a model which relates discounted cash flow to production rate and cumulative number of items produced. This model draws heavily on (i) the characteristics of production on an assembly line and (ii) the efficiency of "crews" of labor at each position on the line. This rather specialized model points the way for the generalization below which is based on standard economic production functions.

In this paper, a homogeneous production function is augmented with the learning hypothesis. The firm is charged with production to a customer ordered defined as a given volume of output available at a known point in time.

The order serves to constrain a production program which is assumed to be carried out by minimizing the discounted cost of producing.

In order to emphasize the impact of the other stock concepts, the services of various capital stocks are treated as flows in this paper. One might imagine the firm leasing capital equipment for varying periods of time. The prices of capital are then rental charges for capital services. Thus capital is not distinguished from other inputs to the production process.

To illustrate the results of this theory, we will assume that relative resource prices do not change during the production program. (They may all increase or decrease at the same rate, however.) This permits us to analyze the production situation as if there were only one "composite" input. Secondly, we will assume a log linear form for the production function.

The model and its solution is described in the next section. These results are compared to traditional learning curves in the Learning Curves Section. The paper is briefly summarized in the Summary Section.

THE MODEL

The variables of the model are described below:

$Q(t)$ = the cumulative quantity of output at t

$\dot{Q}(t) = dQ/dt$ = the production rate at t

$x(t)$ = the rate of resource use at t

p = the resource price

ρ = the discount rate

$\dot{C}(t)$ = the discounted cost of producing $\dot{Q}$ at t

T = the total length of the production period

V = the volume of production on the program attained by T

δ = the elasticity of production rate with respect to cumulative production experience, a parameter describing learning

α = a returns to scale parameter

The production function relates the rate of use of the composite input and production experience (measured by cumulative output to date) to output rate at any point in time. Cumulative production experience is presumed to enter the production function by permitting Hicks neutral technological change as a log linear function of production experience. The resulting production function is written as:

$$\dot{Q} = Q^{\delta} x^{1/\alpha} \tag{1}$$

where $0<\delta<1$ is the elasticity of production rate with respect to production experience and $\alpha>1$ implying decreasing returns to scale.

The discounted cost incurred by producing $\dot{Q}$ at t is defined as:

$$\dot{C} = e^{-\rho t} px \tag{2}$$

The resource price and the discount rate are assumed to be exogeneous constants, independent of time and any of the decisions of the firm. This permits the firm perfect flexibility in resource use. There are no penalties for altering the planned rate of resource use.

The firm is assumed to minimize the discounted cost stream incurred to produce V units of output by time T. The firm's problem may be characterized as:

$$\begin{aligned} &\min \int_0^T e^{-\rho t} px\, dt \\ &\text{s.t. } \dot{Q} = Q^{\delta} x^{1/\alpha} \\ &\qquad x \geq 0 \qquad Q(0) = 0,\ Q(T) = V \end{aligned} \tag{3}$$

This is a problem in optimal control. The details of the solution in a more general context are given in Womer [14].

The nature of the problem can easily be seen by substituting from (1) into (2). This yields the discounted cost function:

$$\dot{C} = e^{-\rho} p \dot{Q}^{\alpha} Q^{-\alpha\delta} \tag{4}$$

This function is illustrated in Figure 1. The nature of the problem is to find the proper time path of production (relation between Q and $\dot{Q}$) to satisfy the constraints and minimize total costs. In the figure, total costs are illustrated by the area of the surface above the relation between Q and $\dot{Q}$.

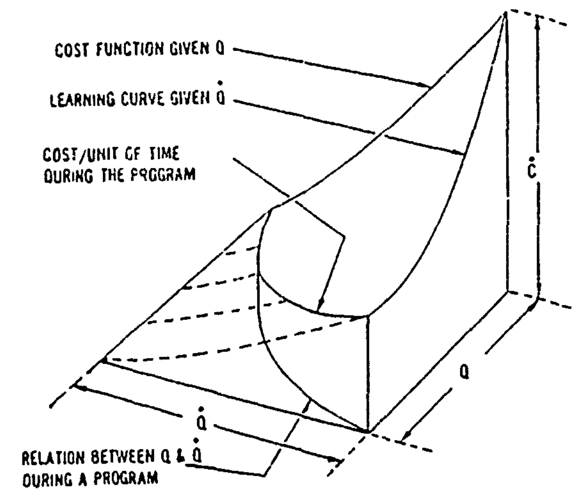

Figure 1. Cost Versus Production Rate and Cumulative Quantity

The mathematical solution to the problem at (3) is given by:

$$Q(t) = V[(e^{\rho t/\alpha-1}-1)/(e^{\rho T/\alpha-1}-1)]^{1/1-\delta} \quad (5)$$

This optimal time path of output increases at an increasing rate with time throughout the program. At any point in time, cumulative production is proportionate to volume and declines with the length of the production period.

Differentiating equation (5) and substituting the result into equation (4) yields:

$$\dot{C} = p\, V^{\alpha(1-\delta)}(e^{\rho T/(\alpha-1)}-1)^{-\alpha} \left[\frac{\rho}{(1-\delta)(\alpha-1)}\right]^{\alpha} e^{\rho t/(\alpha-1)} \quad (6)$$

Here we see the rate of cost grows exponentially with time. Its intercept is determined by prices, volume, the period of production and other parameters.

Equation (6) may be integrated over the length of the production period to determine the total discounted cost of production incurred on a production program defined by V and T.

$$C(V,T) = [\rho/(\alpha-1)]^{\alpha-1}(1-\delta)^{-\alpha}\, V^{\alpha(1-\delta)} [e^{\rho T/(\alpha-1)}-1]^{1-\alpha} \quad (7)$$

The effect of volume on costs clearly is due both to decreasing returns to scale ($\alpha>1$) and learning ($0<\delta<1$). The net effect of these two forces clearly depends on the values of the parameters involved, but conceptually costs may rise at an increasing, constant, or decreasing rate with volume. Since $\alpha>1$ the model does require that discounted costs decline with the length of the program for a given volume of production.

The cost function at equation (7) corresponds to a planning situation. It describes the behavior of production costs for alternative production programs if the time path of production rate is chosen in an optimal manner.

The time path of cumulative production cost for given V and T is found by integrating equation (6) from 0 to t where $t<T$. If we then substitute for t from equation (5) cumulative cost is related to cumulative output at any time in the program by:

$$C(t|V,T) = [\rho/(\alpha-1)]^{\alpha-1}(1-\delta)^{-\alpha}\, V^{(\alpha-1)(1-\delta)}\, p\,[Q(t)]^{1-\delta}\,[e^{\rho T/(\alpha-1)}-1]^{1-\alpha} \quad (8)$$

The impact of cumulative production, $Q(t)$, on costs is different from the impact of planned volume, V. While the impact of volume depends on both the learning and the returns to scale parameters the impact of cumulative production is due to learning.

The cost function at equation (8) describes the relation between output and cumulative costs for a given program. This is referred to as the production situation in contrast to the planning situation.

LEARNING CURVES

A learning curve which relates cumulative discounted costs to cumulative quantity produced is consistent with equation (8). Also, while the "intercept" of the learning curve depends on many factors, its "slope" depends only on the parameter which we have associated with learning. Thus, a learning curve[1] estimated from successive observations on output and cost during a program is consistent with the model.

[1] This discussion implies that the empirical work uses discounted costs in constant dollars although discounting is rarely mentioned in the learning curve literature.

Learning curves are particularly popular as describers of costs on aircraft programs. Unfortunately, the use of learning curves in evaluating new aircraft programs is not always consistent with the model or the estimating situation described above. The distinction between equation (7) and the planning situation to which it applies and the empirical environment in which learning curves are estimated using equation (8) is frequently overlooked. Thus, learning curves estimated as above are used to evaluate plans that relate cost to volume on new programs without regard to the returns to scale parameter. Likewise, cross sectional analyses fail to distinguish between the effects of cumulative output and volume on cumulative costs.

The use of learning curves estimated from production programs for these purposes can be extremely misleading. In comparing alternative programs, volume and time are frequently not fixed. Thus, empirical learning curves estimated without regard to these variations do not illuminate the tradeoffs available.

For example, consider a situation in which aircraft are to be produced in a forty month program. Figure 2 illustrates learning curves for three different production programs. In each case, discounted cumulative average costs are plotted against number of aircraft produced (equation (8) divided by $Q(t)$). The difference among the curves reflects only the fact that their intercept depends on volume of production, all other parameters are the same. Each curve is characterized by $\delta = 2/5$ (approximately a 76% learning curve) and $\alpha = 4/3$.

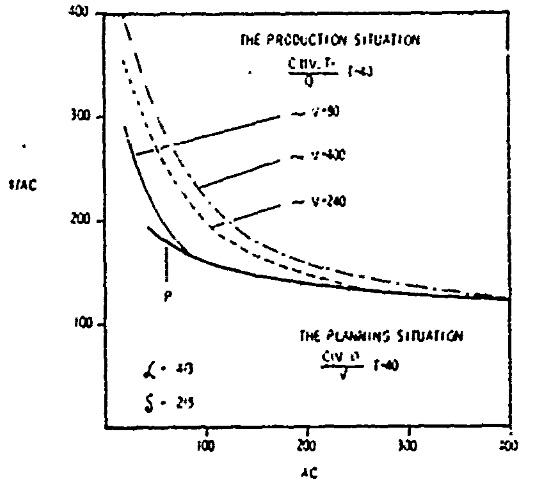

Figure 2. Cumulative Average Costs of Production, $\alpha = 4/3$.

Figure 2 also includes discounted cumulative average costs as a function of planned volume (equation (7) divided by V). Curve P corresponds to this planning situation. The history for any given program is expected to follow the learning curve appropriate for that program's planned volume; but the relation between discounted cumulative average costs and planned volume is given by moving among learning curves along Curve P. In this situation, P has the same general shape as the learning curves, but its slope, which depends on α, is different.

Figure 2 also illustrates the effect of starting a production plan for a large volume and then stopping production before the target is reached. For example, starting a program to produce 240 aircraft in forty months and then stopping after eighty aircraft are produced, yields discounted unit costs approximately 20 percent higher than would have been required had 80 aircraft been planned originally. The original production plan does produce the aircraft in only 26 months, however. This result requires that all those resources which were variable in the planning situation remain so. If some long term contracts for resources were signed in anticipation of a 40 month production program costs would be still higher.

In general, the impact of altering T or V during a production program depends on the contractors flexibility in altering resource use. If the planned usage of some resources cannot be altered during the program, additional constraints must be placed on the model and altering T or V during the program is likely to increase program costs.

A second situation illustrates the effect of α on the relation between the production situations and the planning situation. The curves in Figure 3 differ from those in Figure 2 due to α being increased from 4/3 to 2. While this does not affect the slope of the learning curves, it does change their intercept.

The effect on the planning situation is even more dramatic. Here, decreasing returns are so strong that they overpower the effect of learning so that discounted cumulative average costs increase with planned volume even though each program is still characterized by a 76 percent learning curve.

These two situations clearly demonstrate the effect that decreasing returns to scale can have on aircraft costs. They emphasize the necessity to estimate returns to scale among programs and to augment measured learning curves with this information for planning purposes.

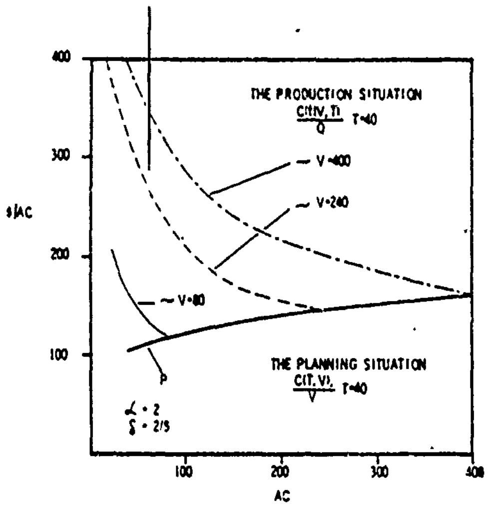

Figure 3. Cumulative Average Costs of Production, $\alpha = 2$.

The above model is also useful in explaining certain puzzling aspects of the empirical work on aircraft costs. Ever since Alchian's 1959 paper [1], RAND Reports [6, 7, 8, 9] on aircraft cost estimation have attempted to include both volume and production rate as independent variables in their cost estimating relations. Even though Alchian's model argues that both variables should be important, the resulting empirical work credits production rate with little, if any, explanatory ability. In fact a recent study [7] concludes

> In general, however, we must conclude that for predicting the overall effect of production rate on aircraft cost, generalized estimating equations based on statistical analyses of our sample of military aircraft would be too unreliable to be useful.

In the above model, unlike Alchian's[2] production rate is a decision variable and is chosen in an optimal manner. Therefore, the model is consistent with the finding that the effect of production rate on costs cannot be distinguished from the effect of volume. This is especially true in the planning situation described by equation (7). If successive observations on costs during a program are to be explained, then equation (8) shows that no time dependent variable (like production rate) other than cumulative quantity produced at "t" is necessary to explain costs.

[2]Other differences between Alchian's model and this one are discussed in [13].

SUMMARY

A model of production was constructed from a production function augmented by learning. The firm was charged with producing to a customer order defined by a given stock of output available at a known point in time. The problem of minimizing the discounted costs of production was then solved to yield the time path of production and the program cost function.

The program cost function was presented in two contexts, the planning situation in equation (7) and the production situation in equation (8). The comparison of these situations illuminated the role of empirically estimated learning curves in the evaluation of alternative production programs, and the impact of altering plans during a production program.

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INTEGRATED MANUFACTURING COST ESTIMATING SYSTEM

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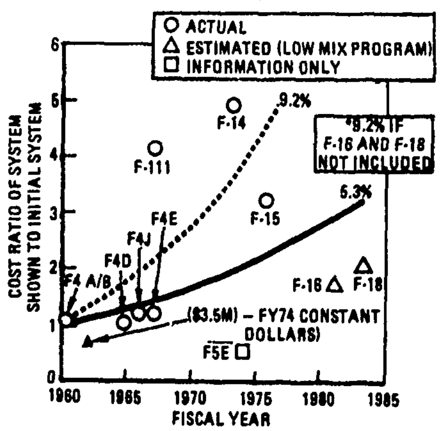
INTRODUCTION

In the past decades, cost has become an increasingly significant parameter in the design and development of aircraft systems. Today, government and industry find themselves operating in an environment that entails the responsibility for selecting design concepts, materials, and processes that, in combination, yield aircraft systems that require the least cost to acquire, operate, and maintain while still achieving performance goals.

Two major reasons can be cited for this current emphasis on cost: increasing ownership costs of aircraft systems (Figure 1 - this figure shows that the average increase in constant dollar terms with inflation removed for fighter aircraft systems exceeds 5%/year compounded in constant dollar terms. That is why the DOD was forced to develop complimentary lower-cost alternatives to the F-14 and F-15 fighters; if left unchecked, fighter aircraft cost growth would have exceeded 9% per annum. If the F-16 and F-18 meet their design-to-cost goals, costs will be reduced to a little over 5% per year) and a downward long-term trend (in constant dollars) of defense procurement funds (Figure 2). Government and Industry are faced with the task of most effectively utilizing these limited funds in the development of aircraft systems, i.e., meet performance goals with a minimum of cost. Several avenues have been investigated to solve this problem. The Design-to-Cost Concept, the implementation of which today is mandatory, has proven to be an effective way of keeping cost at/or below target levels. This concept promotes the closer



*COSTS FOR BASE SYSTEM SHOWN IN CONSTANT FY 74 DOLLARS

FIGURE 1. FIGHTER AIRCRAFT – 100TH UNIT PROCUREMENT COST.①

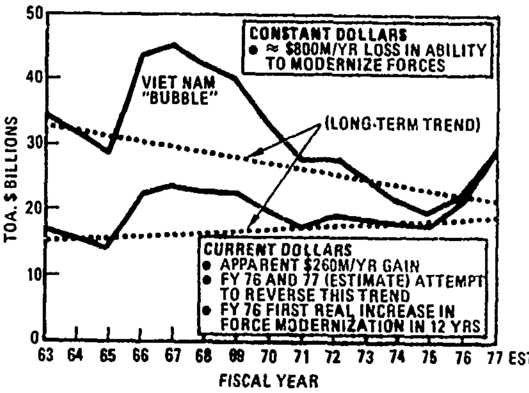


FIGURE 2. DEFENSE PROCUREMENT TRENDS①

①Source: AIIE Presentation entitled the "DTC RFP and Proposal" by Robert E. O'Donohue Jr., Assistant Director (Planning) office of the Director of Defense Research and Engineering. 14 October 1976

integration between the cost and technical communities within government and industry, where cost analysts, in addition to their traditional functions of cost estimating and analysis, become more involved with an sensitive to requirements of the technical groups, while the design and manufacturing engineers become increasingly aware of the cost impacts of their designs and manufacturing plans.

The implementation of the Design-to-Cost (DTC) Concept involves the preparation of tradeoffs whereby feasible alternative designs generated by Design Engineers and manufacturing plans generated by Planners are evaluated on the basis of cost. The main ingredients necessary to effectively do tradeoffs are timeliness, consistency and accuracy. Timely support by cost groups allow technical groups to generate more alternative designs and manufacturing plans thus covering a larger base from which the most cost effective designs and plans can be selected. Consistency and accuracy of estimates provide both cost and technical groups with the confidence necessary for design and manufacturing decisions relating to the manufacture of airframe structures.

Timing is a very significant element to be considered by the cost analyst. Life cycle expenditures for a new system span 20 - 30 years and include development, production, operation and support costs. However, the

major commitment to these expenditures is made during the first five years of the program where approximately 90% of costs are locked in. At the completion of the study (Preliminary Design) phase, product configuration is reasonably well established. When the product is finally prototyped, design is solidified to a point where less than 25% of the anticipated FSD, production and O & S costs can be influenced. By the time production is initiated, tooling concepts, manufacturing and facilities plans will have been sufficiently established that major changes to these nonrecurring costs become costly and impractical. Figure 3 illustrates the degree of commitment to total costs in relation to the timespan of a new systems program.

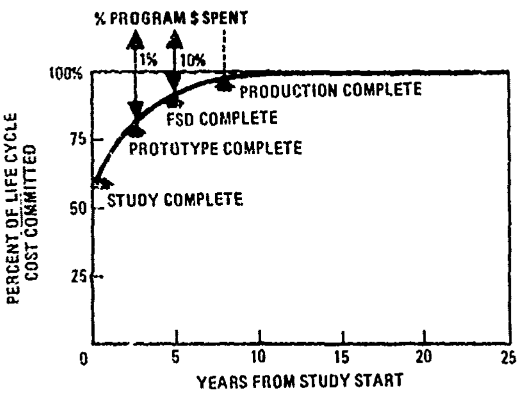


FIGURE 3. COST COMMITMENT

The objective of D-T-C is to increase the number of feasible design alternatives evaluated at this conceptual stage. This allows for a larger base from which to select the most effective designs.

In the past, detail estimating (also called "grassroots" estimating) has been relied upon for consistency and accuracy in estimating. As used by Northrop, this methodology utilizes predetermined standards, usually developed by Industrial Engineers to generate estimates. It uses the "bottoms-up" approach whereby estimates of structures are "built-up" from estimates of detail parts. This "item-by-item" accounting of structures fabrication and assembly costs assures consistency and accuracy in total structures estimates.

The detail estimating approach, however, as it is used today has two major drawbacks: lack of timeliness and high cost. The time and effort required to generate a detail estimate is considerable compared to other estimating approaches, such as parametrics. It requires an extensive amount of input data in terms of design and manufacturing plan definition making it a slow and oftentimes costly process.

Parametric estimating has received wide acceptance within government and industry primarily because of its speed and ease of application. Its accuracy is dependent upon the extent, consistency and homogeneity of the data base from which it was derived. Estimates generated parametrically are usually at a level of aggregation much higher than those generated through detail estimating. The basic reason for this is that actual costs, the base from which parametric relationships are derived, are not tracked at the level addressed by detail estimating. At lower levels, therefore, parametrics becomes insensitive making it ineffective for detail tradeoffs often required in Design to Cost implementation. There is a definite need to develop a tool that is faster, more consistent, and more sensitive for tradeoffs, less costly and more accurate: so that the cost community can become responsive to the requirements of the technical community in the joint effort to get a good handle on cost at the critical conceptual stage.

Realizing this need, Northrop formulated a plan, depicted in Figure 4, that identifies an Integrated Manufacturing Cost Estimating System. This automated system will provide manufacturing cost estimates for metallic and composite structures that are timely, consistent and accurate and at a cost significantly lower than that of manual detail estimating.

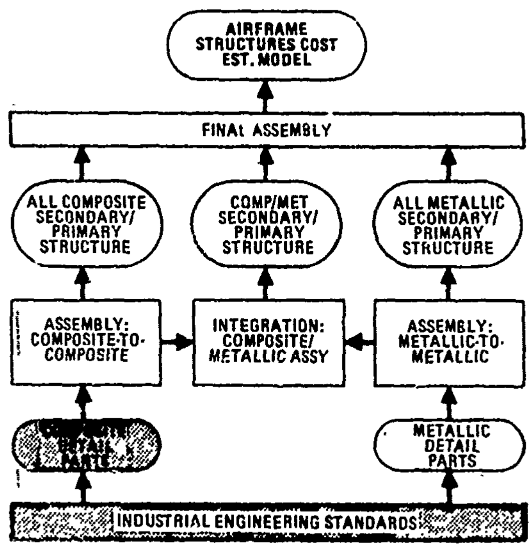


FIGURE 4. STEPS TO DEVELOP AN AIRFRAME STRUCTURES COST ESTIMATING MODEL

The entire system is based on Northrop's Industrial Engineering Time Standards developed by Industrial Engineers over the years through

stop-watch time studies and other predetermined time study techniques. Industrial Engineering Standards provide a base for estimating at levels not obtainable through historical data. Detail operations are studied and time values assigned to their basic elements (PF&D factors excluded) making them valid in any environment so long as operation methods and equipment remain the same.

This paper addresses the development of five modules that cover composite detail parts fabrication, composite assembly, metallic detail parts fabrication, metallic assembly, and metallic/composite integration and final assembly.

BACKGROUND ON ADVANCED COMPOSITES

The first step toward the implementation of this plan was accomplished in the development of the Advanced Composite Cost Estimating Model (ACCEM) - a computer-aided estimating system for advanced composite detail parts fabrication. This model establishes the basic approach by which all other models in the plan are to be developed.

Advance Composites is a new technology that is finding broad applications in the aerospace industry. Initially, advanced composites were developed to exploit their inherent advantages of low weight and high stiffness when compared to conventional structures. Since the material was very expensive in developmental quantities, an increase in costs or at least no cost savings were expected for any aircraft structure in which advanced composites were substituted for conventional metal.

In the late sixties, Advanced Composites technology was characterized by high material costs (close to $300/lb for graphite epoxy), labor intensive fabrication processes, and designs that directly substituted composite material for conventional metals. Since then, through extensive research and development supported by government and industry, and through the ever increasing application of composites in both the aerospace and commercial sectors, we see today composite material costs in the $30-$50/lb range, a variety of composite material forms, an increasing percentage of automation of composite fabrication, development of innovative manufacturing approaches, and innovative designs that stay away from substitution and exploit the inherent advantages of composite materials, i.e., simpler designs that result in less detail parts and require less tools. We see today, more clearly than before, the cost competitiveness of composites when applied to aircraft structures.

The government has been very aggressive in the development of advanced composites technology, as indicated by the increasing dollar value of total RDT&E - composite related - contracts awarded, in spite of a declining total RDT&E contract funding. Table 1 illustrates this for the Air Force Flight Dynamics and Materials Laboratories.

TABLE 1 RDT & E AIR FORCE CONTRACTS RELATED TO AERONAUTICS HANDLED JOINTLY BY AFML & AFFDL*

	FY 75	FY 76	FY 77	FY 78	AVERAGE ANNUAL PERCENTAGE INCREASE (DECREASE)
ADVANCED COMPOSITES	5.6M	7.3M	8.0M	11.1M	18%
ALL OTHERS	1,214.5M	1,407.1M	1,222.0M	1,101.3M	(2%)
TOTAL	1,220.1M	1,414.4M	1,230.0M	1,112.4M	(2%)

From 1975 to 1976, advanced - composite - related contracts increased from 5.6M to 7.3M, a 30% increase; from 1976 to 1977 (7.3M to 8.0M), a 9% increase; from 1977 to 1978 (8.0M to 11.1M) a 14% increase. During this entire time period (1975-1978) total RDT&E funds fell by 9%. Funds spent on advance composites as a percent of total RDT&E contracts has increased from 0.46% in 1975 to 0.52% in 1976, to 0.65% in 1977 and 1.00% in 1980. Other members of the defense community have been equally aggressive in pushing composite structure applications.

ADVANCED COMPOSITE COST ESTIMATING MODEL (ACCEM)

A survey conducted by an Air Force Ad Hoc Composites Study Team in 1975 revealed that one of the major inhibitors to the widespread use of composites, was a lack of confidence in composite cost data due to its non-existents. This problem was recognized by Northrop in 1974 when the company proposed to develop a computerized cost estimating methodology based upon the I.E. Standards approach for advanced composites.

The ACCEM was developed by Northrop under a one-year Air Force/Navy funded contract. The objective of this program was to develop a computerized methodology for estimating the recurring costs associated with the fabrication of advanced composite detail parts. Because advanced composites was a relatively new technology, Northrop felt that the extensive participation of the government and industry members in the development of this

program would make the ACCEM a more useful and worthwhile estimating tool. In the course of developing the ACCEM, therefore, a free exchange of ideas and data was promoted and encouraged through various government/industry briefings conducted by Northrop.

The ACCEM computer model is composed of three modules: Factory Labor Standards Estimating, Support Functions Estimating and Cost Projection. The Factory Labor Standards Estimating Module is the foundation of this methology. It utilizes Industrial Engineering time standard equations to calculate the "pure" labor hours associated with the detail fabrication operations performed for composite parts. In addition, material requirements in terms of total and net usage and scrap are calculated in detail. This computerized procedure is primed by a description of the parts to be fabricated, specifying its construction, the materials used, and the fabrication processes to be performed.

The Cost Projection Module calculates estimated actual factory labor hours at a user-specified production unit by the application of variance factors and improvement curve slopes to the factory labor standard hours generated by the Standards Estimating Module. It also applies the labor, material and overhead rates to arrive at total recurring cost. Estimates of unit, cumulative, and cumulative average cost at specified production units are generated based upon user request.

The Support Functions Estimating Module estimates recurring engineering, tooling, quality control, manufacturing engineering, and graphic services as well as support material through the application of cost estimating relationships (CERs).

An overview of the ACCEM computerized estimating system is presented in Figure 5.

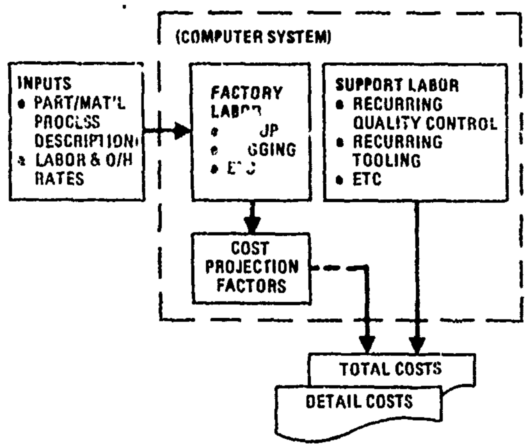


FIGURE 5. ADVANCED COMPOSITE COST ESTIMATING SYSTEM (ACCEM)

ESTIMATING LABOR COSTS

There are four basic steps followed by the ACCEM in estimating labor costs: factory labor standards estimating, T_n-factory labor hours estimating, support labor hours estimating, total labor dollars estimating.

1. STANDARDS ESTIMATING

Standards, as defined in the context of the ACCEM program, represent the time required to perform the basic work content of a task. The total task includes, in addition to basic work content, other activities that do not directly contribute to the fabrication of a part, such as attention to the personal needs, delays, slowdown due to fatigue, coffee breaks, etc. These activities are covered in what is termed "variance," as discussed later.

Factory labor standards estimating is accomplished by Industrial Engineering Standard equations that are "built in" the Standards Estimating Module of the ACCEM. These equations define the standard hours necessary to perform a given operation in terms of physical characteristics of the part that the operation is being performed on.

The equations are primed by description of part construction, process, and material form, which are made through input sheets designed for this program.

Industrial Engineering Standard equations were developed from basic stop watch time studies performed in Northrop of various composite fabrication operations. These operations cover layup, part consolidation, core preparation and finishing. The time studies were plotted using decimal hours and part dimensions as variables. Least squares lines were fitted through these plot points. Equations of these lines define the I.E. Standard equation for that operation.

An example of an I.E. Standard equation for layup of 3" and 12" wide unidirectional graphite tape is presented in Figure 6.

PART COMPLEXITY

The cost estimating system contains factors and equations that quantify the complexity of a composite part. This complexity, defined in terms of bends, is measured by the amount of additional effort required to form the part to its required shape during the layup process. The hours representing this additional

STOPWATCH TIME STUDIES

	TAPE WIDTH	OBSERVED OPERATING TIME PER STRIP — STRIP LENGTH IN INCHES: TO 24	48	72	96	120	144
LAYUP	3"	0.0058	0.0133	0.0174	0.0202	0.0227	0.0247
LAYUP	12"	0.0120	0.0259	0.0414	0.0554	0.0702	0.0833

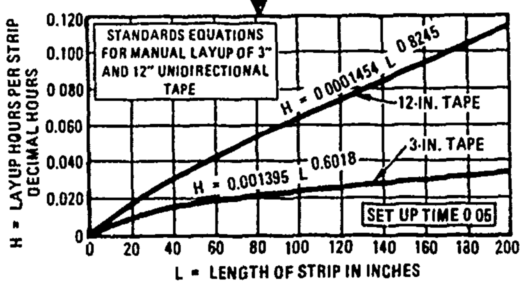


FIGURE 6. LAYUP OF 3" & 12" UNI G/E TAPE

effort are added to the total fabrication hours.

Bends have been classified under two major categories: Straight Bends and Curved Bends. Straight bends have bend lines that follow a straight line pattern. They may be sharp (abrupt change in ply plane direction) or radial (gradual change in ply plane direction, i.e., having a radius of curvature). In addition, straight bends may be described as male (layed up on a male tool) or female (layed up on a female tool). Curved bends have bend lines that follow a curved pattern. They cause either a shrink or stretch condition in the part flanges. Figures 7 and 8 illustrate these different types of bends. The hours associated with each type of bend were derived through a detailed analysis of data collected from actual observation of layup operations. When laying up on bends, extra effort is required to smooth down plies along the bend line. The amount of extra effort required varies for each type of bend and is generally a function of bend length and, when applicable, radius of curvature and flange width. As an example, smoothing down a ply layed up on a male tool along a straight bend simply involves the application of pressure along the exposed bendline. For curved bends, however, pre-heating, cutting of gores or darts and/or stretching of plies might be necessary to obtain the desired part shape. These degrees of complexity have been quantified and are contained in the Standards Estimating Module.

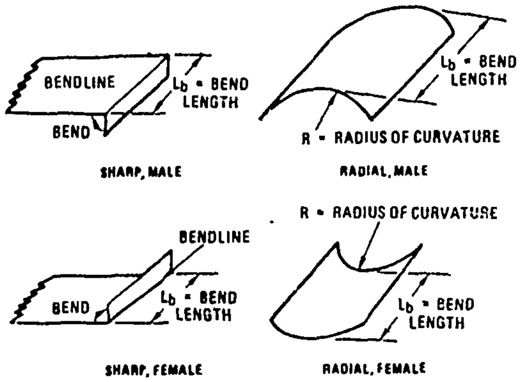


FIGURE 7. STRAIGHT BENDS

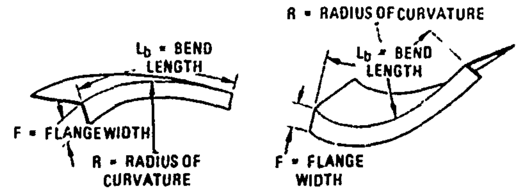


FIGURE 8. CURVED BENDS

2. PROJECTION OF STANDARDS

The standards calculated through the Industrial Engineering Standard equations account only for the basic work content of a task and do not allow for other elements which are part of factory labor as experienced in a real production environment, such as fatigue, waiting time for tools and materials, attention to personal needs, etc. Figure 9 depicts the total work content of factory labor.

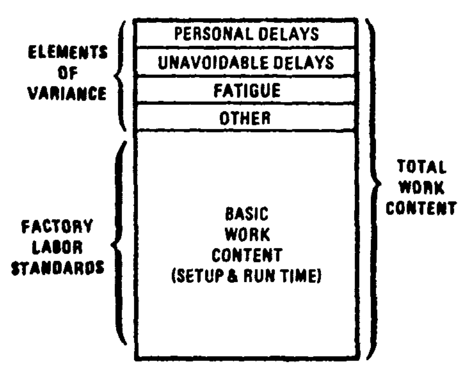


FIGURE 9. FACTORY LABOR BREAKDOWN

Developing estimates of factory labor hours at specified units of production is accomplished by the application of appropriate variance factors to the standards. These variance factors represent allowances for these elements which must be accounted for in estimating the total work content of factory labor.

In applying variances to the standards, the computer calculates the appropriate variance factor by solving the variance equations developed in this program. These variance equations define the factors to be used given the unit number and the process involved, i.e. layup, part consolidation, core preparation or finishing. The variance application routine is performed in the cost projection module of the ACCEM.

The development of the variance and improvement curve equations were based on fiberglass and aluminum honeycomb core fabrication data. Fiberglass experience was selected as a base for developing variances for composite related operations, i.e., layup, part consolidation, and finishing, because of its close similarity to composites particularly in methods of fabrication. Variances for each process, i.e., actual hours divided by standards, were plotted on logarithmic charts.

Analysis of these plots shows the distinctive behavior of variance points in relation to production units, i.e., the initial units have greater fluctuations about a least squares line and show a much steeper slope compared to the latter production units. To more closely simulate these actual experiences and be sensitive to these observed characteristics, the "dog-leg" approach was fitted through the initial 10 plot points (representing units 1 through 10) and then through subsequent points. The two best fit curves were then made to intersect to determine the break point in the "dog-leg" curve. An alternative approach that was investigated was the hyperbolic function of the forms $Y = A + \frac{X}{A + BX}$.

These curves have a shape in the logarithmic grid that is similar to a logarithmic "dog-leg", i.e., the slope of these curves starts out steep and gradually flattens out as the number of units increase. Variance curves for layup, core preparation, part consolidation and finishing are illustrated in Figure 10.

3. SUPPORT LABOR ESTIMATING

Support labor covers the recurring activities performed in support of the factory effort. This includes recurring quality control, engineering, tooling, planning and graphics services. Each of the support labor functions is estimated as a percentage of factory labor.

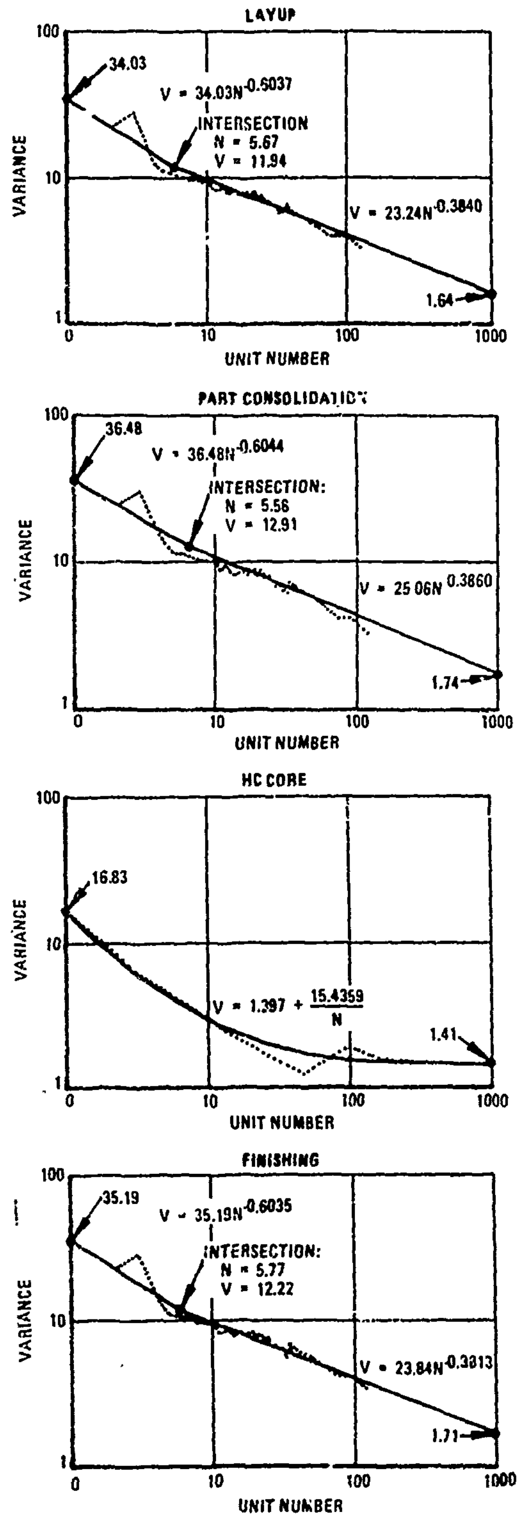


FIGURE 10. VARIANCE CURVES

This procedure follows two steps. First, the appropriate factor is determined by solving the equations that have been developed in the ACCEM for each of the support labor elements. These equations (cost estimating relationships) relate the factors to be applied to labor to the production unit number. The derived factors are then applied to factory labor hours to arrive at labor hours for each support labor element.

The support labor equations were developed based on Northrop's fiberglass fabrication history. The user, however, is provided the option of using his own factors. This option can be exercised through the cost projection input sheets; this automatically preempts the support labor equations contained in the program.

4. LABOR RATES APPLICATION

Labor hours estimates for factory and support are projected to dollars through the application of labor rates, which are provided by the user through the cost projection input sheets of the ACCEM.

MATERIAL ESTIMATING

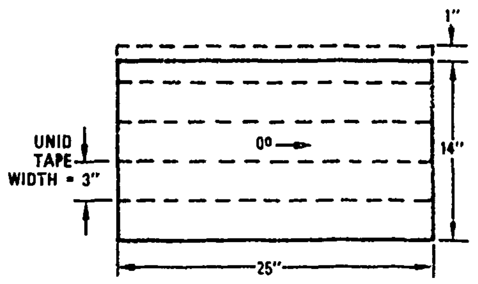
1. PRODUCTION MATERIAL ESTIMATING

Composite material costs are also estimated by the ACCEM's standards estimating module. From inputs that describe the dimensions and orientation of each ply, the computer determines the minimum amount of composite material necessary to cover each ply, in multiples of the composite raw material width. The material used for each ply is then accumulated to determine the total material usage. Scrap is calculated by the difference between the net ply area and the area covered by the material. To illustrate this procedure, an example is presented below.

Production material costs are calculated by taking the net material used in square inches (total material usage - scrap) and converting this into pounds by applying the appropriate density factors resident in the program. The cost per pound of this material is then applied to the weight of the net material used to obtain production material dollars.

2. MANUFACTURING MATERIAL ALLOWANCE

Manufacturing allowance accounts for the cost of rework and scrap material experienced in the production environment.



TOTAL MATERIAL USED = 15 x 25 = 375 sq in.

SCRAP MATERIAL = (15 - 14) x 25 = 25 sq in.

PRODUCTION MATERIAL = 375 - 25 = 350 sq in.

PRODUCTION MATERIAL x THICKNESS x DENSITY (lbs/cu in.) = WEIGHT OF MATERIAL

PRODUCTION MATERIAL WEIGHT x UNIT COST ($/lb) = PRODUCTION MATERIAL COST ($)

PRODUCTION MATERIAL ESTIMATING

The CER FOR Manufacturing Allowance is as follows:

$$MA\$ = (0.02FL\$) + (SCRAP\$)$$

where:

MA$ = Manufacturing Allowance

FL$ = Factory Labor Dollars

SCRAP$ = Scrap Material Dollars

The scrap material costs are calculated in the same manner as production material and becomes part of manufacturing material allowance.

SUPPORT MATERIAL

Support Material consists of purchased parts, equipment standard parts, and process material required to support the fabrication of composite parts. This category covers tooling, engineering and allocated material, and includes such items as vacuum film, Osnaburg cloth, thermocouple wire, teflon, potting compounds, and adhesive agents.

The CER for Recurring Support Material is as follows:

$$SM\$ = 0.30\ (DM\$)$$

where:

SM$ = Support Material Dollars

DM$ = Direct Material Dollars

ESTIMATING LABOR OVERHEAD, MATERIAL BURDEN AND G & A

Labor overhead is estimated by the cost projection module of the ACCEM by applying factors to factory labor dollars. The cost projection input sheets allow the user to enter the appropriate labor overhead factors.

In the same manner, material burden is calculated through the application of material burden rates to total material, i.e., production material, support material and manufacturing material allowance.

General and Administrative costs are estimated as a percentage of total labor and material (including labor overhead and material burden). This percentage is likewise specified by the user in the input sheets.

ACCEM FEATURES

The salient features of the ACCEM that make an effective tool in cost analysis are as follows:

- Estimates in detail -- The model identifies the detail operations involved in fabrication and determines, from its broad Industrial Engineering Standards base, the costs associated with each of these operations. In addition, it is capable of estimating total material usage, costs for each type material, material scrap factor, and weight of the part. As a result, high cost areas related to design and manufacturing processes become readily identifiable - a very significant facet in design/process evaluation.

- Fast -- The computerization of this methodology provides the capability of generating timely cost information. In addition, it quickly responds to changes in a design, material process, and other parameters that im t costs.

- Trade-off Capabi..ty -- This system was designed to be sensitive to alternative manufacturing processes and parts design. This sensitivity provides the user with the capability for determining relative cost differences between alternative designs and manufacturing processes, at a total level or at a detailed level.

  This trade-off capability exists in all phases of composite structures development. At the conceptual level, this system can generate all sample data required to make a reasonable assessment and evaluation of alternative design concepts. The data generated will show in detail the areas where cost differences lie and, therefore, enable the user to determine where, when and why a design concept is more cost effective when compared to other concepts.

- Cost Effective -- The application of the ACCEM requires considerably less time and Manpower than does the manual detail estimating process.

- Adaptability -- The ACCEM has been structured to allow the incorporation of new processes, materials and equipment as data be mes available.

ACCEM MODIFICATION

A project to modify the ACCEM is currently being planned. The objective of this modification is to make the ACCEM an even more effective tool for composite cost analysis. It will incorporate new standards, new methods, new materials and new ideas generated through feedback from the various ACCEM users in industry.

Specific areas identified for modification include:

- Input Methodology

  Inputs to the ACCEM are being redesigned for simplicity and adaptability to an "on-line" mode. The number of input sheets will also be cut down from the current six pages to one.

- Output Data

  The Modification effort will provide users with a selection as to the type of output desired. Three basic types will be provided:

  1) detail-showing all detail operations, parameters, and calculated labor and material;
  2) standard - showing operation categories and calculated labor and material costs;
  3) Summary - showing labor and material costs for the structure.

- Scope

  The scope of the current ACCEM will be expanded to include the assembly of composite parts; other composite materials such as Boron, Kevlar, etc.; material price fluctuations; production

rate changes and their impact on manufacturing costs; new composite manufacturing methods such as automated cutting techniques; automated ply transfer, etc.

- Standards

  Industrial Engineering standards in the ACCEM will be updated based upon most recent Industrial Engineering Studies of composite operations. These new standards will increase the system's accuracy and consistency in estimating.

The ACCEM concept has become the basis or foundation for an extension into other cost estimating modules.

The Second part of Northrop's overall plan is the development of an estimating system for metallic detail parts. Two major models are currently being developed by two project teams in Northrop: The Sheet Metal Automated Cost Estimating Model (SMACEM) and the Machined Parts Automated Cost Estimating Model (MPACEM).

These two models cover the cross-hatched portion of Figure 11.

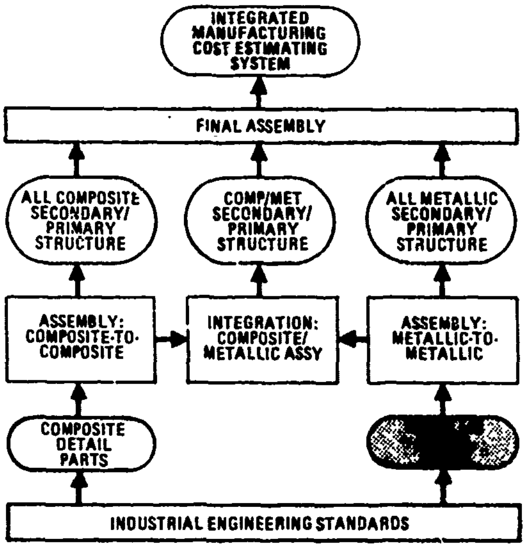


FIGURE 11. STEPS TO DEVELOP AN INTEGRATED MANUFACTURING COST ESTIMATING MODEL

SHEET METAL AUTOMATED COST ESTIMATING MODEL (SMACEM)

Northrop is nearing completion of the development of the computerized methodology for estimating factory labor hours associated with the fabrication of sheet metal parts. The SMACEM will provide an estimating capability applicable to operations including cutting (e.g. shear, saw, rout, punch, drill), forming (e.g., hydropress, brakepress, drawpress, drop hammer, stretchwrap, roll form), and other operations necessary to complete the fabrication of parts made from aluminum sheet stock.

Since a relatively high portion of Northrop's manufacturing effort addresses aluminum sheet metal fabrication, a computerized methodology offered significant potential benefits. The SMACEM will provide these benefits for estimating sheet metal parts as well as serve as a model for the other areas of metals fabrication.

Estimating factory labor hours associated with sheet metal fabrication involves 1) determining the manufacturing concept, 2) defining the manufacturing plan by identifying the operations in sequence, 3) identifying the basic standards data associated with those operations, 4) applying the data to calculate set up and run time, and 5) applying variance factors and learning curves to arrive at estimated hours. The SMACEM approach augments the fundamental Industrial Engineering Standards approach with the application of Standard Manufacturing Plans to assist with step 2) as well as steps 3) - 5).

Standard Manufacturing Plans identify the operations generally involved with a particular manufacturing concept. They aid the planning process by providing a baseline of common elements. These standard plans were compiled from analysis of the shop plans generated for normal production operations.

The SMACEM contains over thirty standard plans from which the user can select and modify if necessary to fit the unique characteristics of the part. Based upon user-specified physical and operational parameters the SMACEM identifies the associated standards basic data and applies the data to calculate set up and run time standards.

As of this writing, the SMACEM computer program is being installed at Northrop, and is expected to be operational in July 1978. The next activity will be to expand the model to cover other materials (e.g. titanium, steel, and magnesium) and forms (e.g. extrusions, tubes).

MACHINED PARTS AUTOMATED COST ESTIMATING MODEL (MPACEM)

The detail cost estimating procedure currently used at Northrop provides a methodology for deriving accurate factory labor cost estimates

for detail machined parts. The procedure is basically a manual effort from the time an engineering drawing or statement of work is analyzed and a process plan developed to the breakdown of the operations into their work content, application of associated labor standards and summarization into a cost package. This procedure is lengthy, time consuming and complex because of the numerous alternate product types, machine capabilities and shop practices to be considered. The current situation is such that cost estimates must be developed faster in order to meet proposal deadlines, yet still maintain an acceptable level of accuracy, consistency and auditability.

The MPACEM will reduce the standards application manhours by controlling most of the manual decision making effort relative to defining the detail work content and applying associated labor and machining standards. The approach will entail use of feasible data management techniques such as grouping data into higher level categories or averaging labor standards based on analysis of types of products and machining methods. Furthermore, it's conceivable that techniques used in existing computer systems developed by other companies will be incorporated in MPACEM when the methodology or standard data are compatible.

MPACEM will tie-in to Northrop's future Computer Aided Manufacturing (CAM) system and other business systems. The CAM project is planned to integrate the design, process planning and standards application functions. The benefits associated with CAM are encouraging and represent a tool to increase the productivity of today's cost estimator.

SYSTEM DESCRIPTION

MPACEM will have the capability of 1) providing set up and run standard hours by machine type, operation and work element, 2) providing a summary total of standards by part and 3) providing timely output reports and various formats. Furthermore, the system will be designed so as to minimize the · e to maintain the system logic or create n· output formats.

This system will replace most of the current manual effort associated with defining the work content of detail machined parts, applying labor standards to the work content using Northrop's Basic Standard Data Manual and preparing all handwritten backup documentation. These objectives will be achieved with computerized methodologies initiated by input data provided by cost estimators defining the part size and shape, material type, machine types, machining operations, holding devices, cutting tools and metal removal requirements. Using this input data, the system will compute 1) the applicable work elements and labor standards, and 2) machining feeds and speeds, number of cuts and machining standards. The logic will be developed from detailed analysis of the present and expected standard application methodologies. Currently, they are not well defined or standardized. Each estimator utilizes his own decision paths to determine the methods and standards to manufacture a part. Since there are several alternate manufacturing paths and interpretations of the data in the Basic Standard Data Manual, standard application inconsistencies do occur. This system will direct estimators toward more accurate and consistent results by minimizing the subjectivity associated with interpreting the Basic Standard Data Manual.

PARAMETRIC MODELING

Our previous discussion has been couched in terms of addressing Northrop's cost estimating methodology and the expansion of the Advanced Composite Cost Estimating Model as well as the development of estimating systems for sheet metal fabrication and the machining of metallic parts. As you recall, all of these systems are based upon "grassroots" estimating i.e., total structure estimates are built up from detail estimates of the structure's components.

However, parametric estimating which is based on Cost Estimating Relationships (CER's) is still with us and is accepted and widely employed by both government and industry because of its speed and ease of application. This technique utilizes mathematical relationships, also called Cost Estimating Relationships (CER's), derived from historical data that relate physical parameters of a structure to cost. Parametric equations range from very gross rules-of-thumb type relationships to more detailed multi-variate equations. Its accuracy is dependent on the extent, consistency and homogeneity of the data base from which it was derived. For new technologies, such as advanced composites, relevant historical data is lacking or non-existent. A by-product of Northrop's effort in the development of automated estimating systems based on Industrial Engineering Time Standards will be the capability of generating a homogeneous set of cost data to derive CER's. This data will be virtually unlimited; thus the potential for increased accuracy and reliability will be substantially enhanced and far superior to current CER's that are based on historical data. See Figure 12.

Dependent variables, such as factory labor, standard hours, total recurring co...s, etc., and independent variables, such as weight, surface area, etc., can be abstracted from the outputs of the ACCEM, the SMACEM, and the MPACEM. For example, regression analysis can

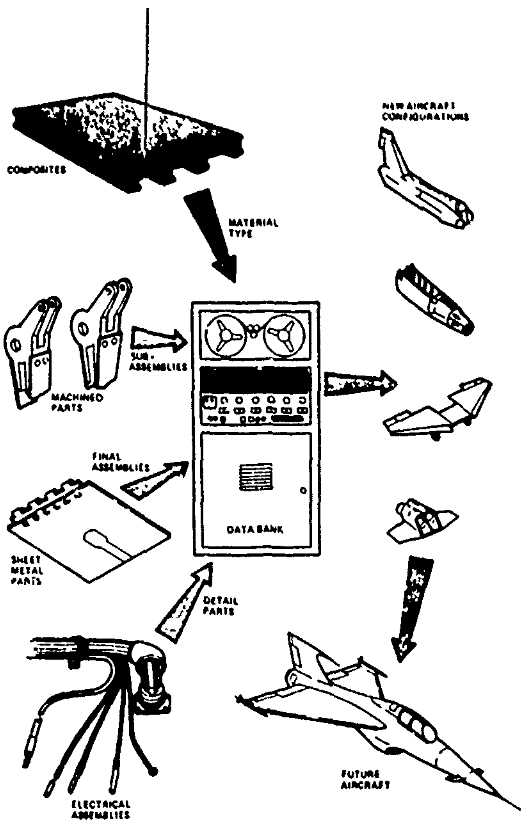


FIGURE 12. PARAMETRIC ESTIMATING

be performed relating surface area and standard hours in an unlimited number of generated outputs with the resulting equation (CER) used for parametric estimating. An increase in the number of estimates generated will increase the accuracy and reliability of the relationship. This capability can be expanded by adding parts to make up assemblies; by adding assemblies to make up sections; and by adding sections to make up the total airframe. This will provide Northrop with a total cost data bank. For example, if a request is made by the United States Government for a cost estimate for a new fighter aircraft and the only information which is provided is the approximate size, type of construction and material form. With just this information being designated Northrop will have the capability to generate an estimate for the aircraft in detail by just changing a few cards in the data set.

SUMMARY

Cost has become a significant parameter in the design and development of aircraft systems.

Design-to-Cost is a concept that is being implemented throughout industry to attain better control of cost. especially at the early stages of aircraft systems development.

To be effective, Design-to-Cost tools must be available during the early stages of design development. Current tools for estimating, i.e., parametrics and "grass-roots" have their merits but are inadequate for the requirements demanded by Design-to-Cost (i.e., accuracy, speed, and sensitivity to detail design and manufacturing process variations).

To respond to these requirements, Northrop has implemented a plan to develop a computerized methodology utilizing the Industrial Engineering Standards approach. The first phase of this plan was accomplished in the development of the Advanced Composite Cost Estimating Model (ACCEM) funded by the Air Force and the Navy.

A capability similar to the ACCEM is currently being developed in-house for metallics. The final goal of this plan is the development of the Integrated Manufacturing Cost Estimating System which will estimate costs of total composite/metallic airframes and structures in detail as well as for proposed weapon systems by parametric sizing.

SOURCE SELECTION

IN DEFENSE OF BEST-AND-FINAL OFFER

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It is time that someone spoke up for that much-maligned event in the source selection process called best-and-final offer. The most interesting aspect in the continuing bitter and biting criticism of that process is that it comes primarily from the aerospace industry. One of the latest was an article in the Defense Systems Management Journal which alleges that the "procedures places (sic) the procurement process in the realm of a used car auction . . ." (1:2 and 1:3) There are still a few of us around (but apparently not many!) who remember that the process was instituted as a result of complaints by that same industry. They very vigorously and insistently stated that some common cutoff date had to be established to prevent auctioning. How then did the best-and-final offer, which was devised to resolve that complaint, later become the culprit in new allegations of auctioning?

Let us review some history. In 1959, the ASPR read as follows:

"(a) The normal procedure in negotiated procurements, after receipt of initial proposals, is to conduct such written or oral discussions as may be required to obtain agreements most advantageous to the Government. Negotiations shall be conducted as follows:

(i) where a responsible offeror submits a responsive proposal which, in the contracting officer's opinion, is clearly and substantially more advantageous to the Government than any other proposal, negotiations may be conducted with that offeror only; or

(ii) where several responsible offerors submit offers which are grouped so that a moderate change in either the price or the technical proposal would make any one of the group the most advantageous offer to the Government, further negotiations should be conducted with all offerors in that group. Whenever negotiations are conducted with more than one offeror, no indication shall be made to any offeror of a price which must be met to obtain further consideration, since such practice constitutes an auction technique which must be avoided. No information regarding the number or identity of the offerors participating in the negotiations shall be made available to the public or to anyone whose official duties do not require such knowledge. Whenever negotiations are being conducted with several offerors, while such negotiations may be conducted successively, all offerors participating in such negotiations shall be offered an equitable opportunity to submit such pricing, technical, or other revisions in their proposals as may result from the negotiations. All offerors shall be informed that after the submission of final revisions, no information will be furnished to any offeror until award has been made. Modifications of proposals received after the submission of final prices shall be considered only under the circumstances set forth in ASPR 3-804.2(b) (relating to late proposals)." (1:343)

Note that we could negotiate with only one proposer, if, in the judgment of the contracting officer, that one proposal was clearly the best.

Also note that, if negotiating with more than one proposer, "auction techniques" were forbidden, but the reference is in relation to improper indication of a price which must be met. Multiple negotiations could be held successively with those who submitted technically acceptable proposals, but each must be offered an opportunity to submit a "final revision." There is no mention of a single cutoff date for all revisions.

In practice what happened was that proposers maneuvered very carefully not to be the first to submit "final revisions." Their reasoning was that they were afraid those prices would leak and their competitors would come in below them. Sometimes they submitted a revision consisting of a portion of that which they were willing to reduce without calling it "final" and waited to see if the contracting officer was going to accept it or if he was going to negotiate with someone else. If the proposer found that in fact negotiations were going on with others, he often submitted another revision. The situation became like a game of tennis with three or four balls in play.

There were many criticisms of this system. There were accusations from industry that evaluators and/or contracting officers were arbitrary in their decisions to negotiate with only one proposer; there were claims of leaks (deliberate or otherwise) which led to auctioning. Contracting officers complained of harassment by aggressive competitors during the successive negotiation cycles and of an inability to pin proposers down to a "final revision."

In 1962, the ASPR was revised to alleviate some of these perceived ills. Excerpts of that issue follow:

"(a) After receipt of initial proposals, written or oral discussions shall be conducted with all responsible offerors who submit proposals within a competitive range, price and other factors considered. . .

(b) . . . Whenever negotiations are conducted with several offerors, while such negotations may be conducted successively, all offerors selected to participate in such negotiations (see 3-805.1(a) above) shall be offered an equitable opportunity to submit such price, technical, or other revisions in their proposals as may result from the negotiations. All such offerors shall be informed of the specified date (and time if desired) of the closing of negotiations and that any revisions to their proposals must be submitted by that date. All such offerors shall be informed that any revision received after such date shall be treated as a late proposal in accordance with the 'Late Proposals' provisions of the request for proposals . . ."(2:354.1)

Note the requirements to negotiate with all those "within a competitive range," the first time that phrase appears. Contracting Officers were required to inform proposers of a specified date and time of closing of negotiations and to apply the provisions concerning late proposals after that date.

This revision deleted the authority to negotiate with only one proposer unless award could be made without further discussion, and unless a notification as to that possibility had been placed in the request for proposal.

Now, we had ostensibly taken care of the problems under the previous method, but note that "competitive range" was in no way defined. Also, there was still latitude for the contractors to submit more than one revision since the words "best-and-final offer" or "common closing date" do not appear.

So once again we had allegations of unfair limiting of numbers of competitors and the contracting officer was beseiged by numerous changes from the competing contractors up until he declared negotiations "closed."

The words regarding best-and-final offer and common closing date are relatively recent. They did not appear in the ASPR until May 1973.

And where are we today? Since 1962, up until the recent test of the so-called "four-step" approach, contracting officers have had no latitude to negotiate with only one proposer. They have carried on extensive parallel negotiations with all those in the competitive range and competitive range is given a very broad interpretation in the current ASPR.

At the end of these dicussions/negotiations, all competitors remaining in the competitive range have one final opportunity to submit revisions which (since 1973) must be received by a common cutoff date established by the contracting officer.

What complaints came from this system? First we have had the allegation that we do technical leveling in our discussions, but most of all we have had the allegation that best-and-final offer procedures constitute auctioning. The problem is that we hear that complaint, no matter what method is used to close negotiations but we hear no solutions. It will be very interesting to see what comes out of the requirement in the four-step approach for a common cutoff date for final proposals. Even though negotiations may subsequently take place with one offeror, won't that common cutoff date be viewed by industry as a last-and-final chance and therefore be considered as having auctioning overtones?

In fact, such allegations were made in connection with the test cases, i.e., that contractors offered buy-in proposals at this point, after having "discovered" that competitor(s) were below them in price. (3:20)

I consider some common cutoff date a necessity unless we return to the 1959 system of discussing/negotiating only with the one who appears best technically on the basis of the original proposal without allowing any revisions. It appears that negotiating with one proposer is economical, both to the Government and to industry. Would industry be willing to accept the fact that, if they misunderstood the terms of the request for proposal in any way, they would not have an opportunity to offer supplemental or corrected material? Would the Government be willing to take that same chance, that someone highly competent might misconstrue and thereby lose all opportunity for award? Some Government negotiators offered as a criticism of the test of the four-step approach, the inability to hold any extensive discussions prior to selection of the one with whom to negotiate. But we must keep in mind that GAO has ruled that there must be an opportunity at a common time for best-and-final offers if any questions are discussed with any of the proposers, and therefore we are immediately back to the perception of auction if any discussions are necessary.

Or, even if we negotiate with more than one, would we really want to complete negotiations down to a firm handshake on price? Would the contracting officer be accused of deliberately accepting offers that were noncompetitive in order to force out some proposers?

In 1972, in an article printed in the NCMA Anthology, a vice-president of one of the major aerospace contractors, in discussing a then-new NASA directive, stated that the directive ". . . also recognizes that efforts to obtain, in the process of evaluation and selection, detailed commitment in contractual form from each of the competing sources lead inevitably to auction techniques . . ." (4:83) So, if we tried to establish firm, final agreement during the negotiation process, we would return once more to the old allegations of auction.

The four-step method is an attempt to compromise the obvious disadvantages posed by the above questions. It has many positive aspects, although I do not believe it will eliminate the problem of buy-in or allegations of auctioning as long as we have "discussions" followed by a best-and-final offer, even though that process precedes negotiations with one offeror.

While there has been much ado in recent years concerning the erosion of the authority of the contracting officer, it appears highly unlikely that we will be able to revert to the authority he had in 1959. If we could, then at least on smaller or less complex procurements, which do not require full scale source selection procedures, we could permit the selection of one competitor with whom to negotiate without any requirement for discussion and revisions. The mere fact that this could be done would force the submission of the best possible offer on the first round of proposals, and selection of one with whom to negotiate under that system would eliminate any need for best-and-final offers.

However, having experienced the difficulties that can be caused by numerous, uncontrolled "revisions" in the 1959-62 era, it does not seem realistic or practical or desirable to eliminate a common cutoff for revisions, including price revisions, if discussions or negotiations or clarifications--call it what you wish--are going to go on with several proposers, either under the four-step method or under the system of parallel negotiations. Notwithstanding the criticism leveled at best-and-final offer, it seems the only fair way. It can be abused, but I believe the allegations of abuse to be overstated. Repetitive requests for best-and-final offers are not the norm. Nevertheless, any administrative procedure can be abused and this one has been both abused and misused by both parties. Nevertheless, there seems to be no reasonable alternative. It is not credible that proposers or the contracting officers want to return to a system of repetitive revisions precipitated by the competitors' perception of where they stand in the competition as the source selection process evolves. Without some provision for a date for the final offer, that is exactly what would happen--again!

REFERENCES

(1) Defense Systems Management Review, Vol I, No. 4, Autumn 1977, "Can Weapon System Procurement be Managed?" by Dr. Albert J. Kelley.

(2) Armed Service Procurement Regulation, 1 October 1959, 3-805.1

(3) Armed Services Procurement Regulation, 30 September 1969, Rev II, 3-805.1.

(4) Electronic News, April 11, 1977. "Out of Step" by Jack Robertson

(5) H. W. Neffner, The Boeing Company, reprinted in Vol 2, NCMA News Letter Anthology, January 1973, from a speech given February 11, 1972 in Los Angeles, California, South Bay Chapter, NCMA.

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FOUR-STEP SOURCE SELECTION
MEANINGFUL DISCUSSIONS STILL A PROBLEM

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As part of revised Department of Defense (DOD) Directive 4105.62, "Selection of Contractual Sources for Major Defense Systems", a service test of a four-step source selection concept for the selection of sources and negotiation of contracts for advanced, engineering and operational systems development was established.[1] The four-step process was initiated to improve weapons systems source selection and to correct the alleged procurement abuses of government technical leveling and auction techniques, and industry buy-ins.[2]

The four steps in the process are briefly summarized as follows:

(1) Solicitation, submission and evaluation of technical proposals,

(2) Submission and evaluation of cost/price proposals,

(3) Selection of contractor, and

(4) Negotiation and award of definitive contract.[3]

The Armed Services Procurement Regulation (ASPR) language applicable only to the special four-step test process was promulgated in Defense Procurement Circular (DPC) 75-7, Feb. 27, 1976[4], and modified the ASPR 3-805.3 (1975 edition) language by adding the following paragraph dealing with Discussions with Offerors:

> (b) In discussing technical proposals for procurements involving advanced, engineering or operational systems development (see (4-101)), contracting officers shall apprise offerors selected to participate in discussions of only those identified deficiencies in their proposals that lead to a conclusion that (i) the meaning of the proposal or some aspect thereof is not clear, (ii) the offeror has failed to adequately substantiate a proposed technical approach or solution, or (iii) further clarification of the solicitation is required for effective competition. <u>Technical deficiencies clearly relating to an offeror's management abilities, engineering or scientific judgment, or his lack of competence of inventiveness in preparing his proposal shall not be disclosed.</u> Meaningful discussions shall be conducted with the respective offerors regarding their cost/price proposals. Such discussions may include:
>
> (i) cost realism;
> (ii) mathematical errors or inconsistencies;
> (iii) correlation between costs and related technical elements, and
> (iv) other cost/price factors necessary for complete understanding of both the Government requirement and the proposal for meeting it, including delivery schedule, other contract terms, and trade-off considerations (with supporting rationale) among such elements as performance, design to cost, life cycle cost, and logistic support. Offerors shall be afforded a reasonable opportunity to correct or resolve deficiencies and submit revisions to either their technical or cost/price proposals.[5]
> (Emphasis added)

The normal (not the special test) language of ASPR concerning discussions with offerors provides for the identification of proposal deficiencies in the technical and cost/price areas and the opportunity for offerors to submit revisions to proposals based on those discussions. Importantly, a "deficiency" is defined, "as that part of an offeror's proposal which would not satisfy the Government's requirements."[6]

This dichotomy in handling discussions of proposal deficiencies between the normal and special test programs has caused misunderstanding and confusion on the part of both industry and government.

Although seventeen DOD programs were selected as four-step test program candidates,[7] only two have gone through the complete procurement cycle including protest to the Comptroller General of the United States.

The grounds of protest to the General Accounting Office (GAO) in both the protest of <u>AiResearch Manufacturing Company of Arizona</u>[8] and <u>GTE Sylvania, Inc.</u>[9], centered, <u>inter alia</u>, on the Government's alleged failure to conduct meaningful discussions in violation of DOD Directive 4105.62. The meaningful discussion issue arose primarily because the government four-step evaluators and negotiators are not permitted to discuss an offeror's technical proposal deficiencies relative to his

management abilities, lack of competence or inventiveness, or engineering or scientific judgment. During the discussion period offerors may be apprised only of those identified deficiencies in their proposals that lead to a conclusion that "(a) the meaning of the proposal or some aspect thereof is not clear (b) the offeror has failed to adequately substantiate a proposed technical approach or solution, or (c) further clarification of the solicitation is required for effective competition."[10] Thus both industry and government contract negotiators have difficulty in determining what constitutes a proposal deficiency vis-a-vis a proposal clarification.

Although distinguishing between proposal deficiencies and proposal clarifications is relatively new to DOD participants in the four-step selection process, GAO has had occasion to deal with similar matters in several NASA procurements.[11] The DOD four-step source selection procedures are very similar to NASA's in that discussion of proposal deficiencies or weaknesses are specifically prohibited.[12] Both procedures state the need to allow competitive-range offerors the opportunity for discussions of technical proposals to clarify or substantiate the proposal, or clarify solicitation meaning when needed. Also the procedures specifically prohibit discussions of technical weaknesses (NASA's term) or deficiencies (DOD's term) relating to an offeror's lack of competence, diligence, inventiveness, or lack of management abilities, engineering or scientific judgment.[13]

Since the DOD procedures are comparable to the NASA procedures, GAO has used their prior decisions involving NASA procurements as an aid in deciding the DOD four-step source selection process protests.[14]

In deciding both AiResearch and GTE Sylvania, GAO utilized their lengthy decision dealing with the selection procedure for the space shuttle main engine contractor.[15] GAO wrestled with the conflict between NASA's limited discussion rule and the 10 U.S.C. 2304(g) (1970) statutory requirement that "written or oral discussions shall be conducted with all responsible offerors who submit proposals within a competitive range, price, and other factors considered." GAO discussed the legislative history of the statute and concluded that while the statute did not define the nature, scope, or extent of the required discussions, it was clear in their view that competition was to be maximized and that discussions be "meaningful by making them discussions in fact and not just lip service."[16]

GAO has indicated that discussions, to be meaningful, must include the pointing out of deficiencies in an offeror's proposal.[17] However, GAO has recognized that limitations can be placed on the extent and content of discussions in order to avoid transfusion or leveling,[18] as evidenced by the NASA and DOD procedures.

In the protest of Sperry Rand Corporation,[19] GAO interpreted the phrase "discussions with offerors within the competitive range" to include the identification of ambiguities and uncertainties, but not technical deficiencies. The underlying rationale is that to point out deficiencies during discussions would unfairly compromise the competitive process by leveling the technical disparities between the weak and strong competitors.[20]

GAO has acknowledged the potential in research and development procurements for the disclosure to other competitors of the "fruits of an offeror's innovative efforts."[21] Thus, the weaknesses in a protestor's proposal were deficiencies only in comparison with relative strengths of the selected company. Therefore, discussions concerning deficiencies and comparative weaknesses would inevitably involve technical "leveling" and "transfusion".[22] To avoid this technical transfusion and leveling, discussions could be properly limited to the clarification of proposals. Thus, " . . . where the meaning of a proposal is clear and [evaluators have] enough information to assess its validity and the proposal contains a weakness which is inherent in the proposer's management engineering or scientific judgment or is the result of its own lack of competence or inventiveness in preparing its proposal, the contracting officer shall not point out the weakness."[23]

GAO on ruling on the question of whether or not the statutory requirement for discussions required the identification of all deficiencies and weaknesses, stated:

> . . . [It] is a matter of judgment primarily for determination by the procuring agency in light of all the circumstances of the particular procurement and the requirement for competitive negotiations, and that such determination is not subject to question by our Office unless clearly arbitrary or without a reasonable basis. However, the statute should not be interpreted in a manner which discriminates against or gives preferential treatment to any competitor. Any discussion with competing offerors raises the question as to how to avoid unfairness and unequal treatment. Obviously, disclosure to other proposers of one proposer's innovative or ingenious solution to a problem is unfair. We agreed that such 'transfusion' should be avoided. It is also unfair, we think, to help one proposer through successive rounds of discussions to bring his original inadequate proposal up to the level

> of other adequate proposals by pointing out those weaknesses which were the result of his own lack of diligence, competence, or inventiveness in preparing its proposal.[24]

The protest of GTE Sylvania, Inc.[25] took a somewhat different tack on the issue of what constitutes meaningful discussions. The protestor alleged major, material changes to the winner's proposal in step four of the procurement process. The DOD Directive explicitly states what can and cannot be discussed in step four, i.e., final negotiations leading to a definitive contract:

> Negotiations after selection <u>shall not involve material changes</u> in the Government's requirements or the contractor's proposal which affect the basis for source selection. In the event that such changes are desired by the Government, the competition will be reopened in accordance with existing ASPR requirements.[26] (Emphasis added)

In the instant protest the Air Force admitted substantial changes amounting to a 35 percent increase in cost. however, such changes did not effect the "basis for source selection."[27]

GAO has previously held that where award of a cost-reimbursement contract is contemplated, the importance of analyzing proposed costs in terms of their realism is apparent, since, regardless of the proposed costs submitted the Government will be obliged to reimburse to the contractor its allowable costs. It is important that the Government contracting personnel exercise informed judgments as to whether proposals are realistic with respect to proposed costs and technical approach, and lack of realism may result in upward adjustment to an offeror's costs.[28]

While GAO has stated that the proper time for exploring costs of proposals within a competitive range is during negotiations and not after receipt of best and final offerors,[29] they have approved of the Government's decision to make significant cost and adjustments to proposals after best and final offers are in.

In the protest of Bell Aerospace Company[30], a non-NASA, non-four step procurement which did not expressly provide for this adjustment process, GAO said:

> We see no significant difference between a process which allows cost adjustment of proposed costs after the close of discussions for purposes of determining the successful contractor - even though no formal adjustments of contract price is formally made - and an undisclosed cost adjustment process used in award selection which ultimately results in a changed contract price more in line with the Government evaluated price as was done here.[31]

It is interesting to note that while the NASA and DOD procedures track closely provision for pro[illegible]n, NASA has no comparable provision dealing with negotiations involving material changes in the final step of the selection process.[32]

This difference in the two procedures did not apparently bother GAO because, "both contemplate cost and technical adjustments in the selected proposal prior to award based on negotiations."[33]

GAO went on to say while they approve that significant percentage adjustments can be made in the selected offeror's proposal, such approval is based on assumptions that adequate cost and technical discussions have been previously conducted among competitive-range offerors; that all offerors have been permitted to submit best and final offers as a result of those discussions; that the Government projections of ultimate changes in the successful offeror's proposal are sound; and that the ultimate changes in the successful offeror's proposal do not affect the underlying assumptions which prompted the selection.[34]

In summarizing the GAO rules on what constitutes meaningful discussions, the Comptroller General has stated that, "extent and content of meaningful discussions . . . are not subject to any fixed, inflexible rule,[35] and "what will constitute such discussion is a matter of judgment primarily for determination by the procuring agency in light of all the circumstances of the particular procurement and the requirement for competitive negotiations . . . ."[36]

As can be seen GAO's many pronouncements on meaningful discussions center on the maintenance of effective competition, and equal and fair treatment for all offerors within a framework which preserves the integrity of the procurement system and assures that the Government procures the goods and services which it requires on terms advantageous to the Government. Unfortunately the voluminous GAO comments on what constitutes "meaningful discussions" really gives little guidance to government and industry contract negotiators.

In at least one protest to GAO, the contracting officer decided that negotiations should be limited to price alone, as it was believed that discussions would have compromised the technical proposals through transfusion of ideas, methodology, and concepts.[37] While looking at such limitations on meaningful

discussions in the abstract, they could become so limited in scop and content that the discussions would amount to nothing more than "a ceremonial exercise with meaningful discussions transposed almost entirely into the final negotiations stage."[38] Conceivably, other contracting activities might ignore the tenor of the DOD Directive and conduct business as usual and have full blown negotiations rather than meaningful discussions within the context of the four-step directive.

It appears from close analysis of the GAO discussions of the AiResearch and GTE Sylvania cases that the government and contractor negotiators in the four-step process are often compelled to engage in potentially harmful word games. The government negotiator must carefully couch questions in very precise language to convey concerns relating to the offeror's proposal without violating the four-step procedures. Thus, while a question simply asks for clarification of the proposal, an offeror inevitably will search for possible hidden meanings. With this sort of transaction it is questionable whether or not the minds of the parties really meet prior to actual negotiations in step four. Since real negotiations do not commence until after the potential contractor has been selected, the potential for material changes in the final step based on misunderstandings is ripe. Or, on the other hand, a competent offeror might be eliminated from step four due to the fear of government representations of the likelihood of technical leveling.

The perceived fear of technical leveling may sacrifice the welfare of individ DOD programs in the name of the integrity of the procurement process. The suggested simple solution of forcing offerors to present their best proposal initially loses sight of the overall government's desire for scientific and technological superiority, especially in the area of research and development, which can only be achieved through full understanding by both parties.[39]

With more and more DOD procurements coming under the mantle of the four-step procurement process, it is anticipated that GAO will be frequently called upon to refine the meaningful discussion problem within the foregoing context. The determinative issue from GAO's standpoint is not necessarily whether meaningful discussions were conducted, but whether effective competition was maintained and whether offerors were permitted to compete on an equal basis.[40]

It is suggested that rather than the overly restrictive and obviously confusing language contained in the DOD Directive pertaining to the scope of meaningful discussions, a simple, concise statement that procuring activities shall not indulge in technical leveling during discussions would suffice.

In order for the government to obtain the optimum goods and services it desires, more liberal interpretations as to the extent of discussions should be permitted in order to fully inform offerors without misunderstanding of government requirements and eliminate problem areas in proposals, without technical leveling.

FOOTNOTES

1. Issued January 6, 1976, by the Deputy Secretary of Defense. See ASPR 4-101 for definitions of advanced, engineering and operational systems evelopment.

2. "4-Step Sourc Selection", A Study to Test and Evaluate New Source Selection Procedures, Interim Report, 31 July 1977.

3. Section III.D.5, DOD Directive 4105.62, supra note 1.

4. Implementing instructions to start the service test of the four-step source selection process had been issued by Deputy Assistant Secretary of Defense for Procurement (I&L) Memorandum Oct. 28, 1975, and was reaffirmed and clarified by a similar memorandum of Mar. 4, 1976.

5. The existing ASPR 3-805.3 language was unchanged except for renumbering paragraphs. It should be noted that the Armed Services Procurement Regulation (ASPR) was replaced by the Defense Acquisition Regulation (DAR), effective Mar. 8, 1978

6. ASPR 3-805.3(a) (1976 edition):

> All offerors selected to participate in discussions shall be advised of deficiencies in their proposals and shall be offered a reasonable opportunity to correct or resolve the deficiencies and to submit such price or cost, technical or other revisions to their proposals that may result from discussions. A deficiency is defined as that part of an offeror's proposal which would not satisfy the Government's requirements.

7. See note 2 supra. Not all selected procurements had to meet the DOD Directive 5000.1 definition of a major program, i.e., $50 million in projected R&D funds or $200 million in projected production funds.

8. 56 Comp. Gen. 989 (1977).

9. Comp. Gen. Dec. B-188272, Nov. 30, 1977.

10. ASPR 3-805.3 test language supra.

11. *See e.g.*, 55 Comp. Gen. 802 (1976); 55 Comp. Gen. 715 (1976); 54 Comp. Gen. 562 (1975); 54 Comp. Gen. 408 (1974); and 53 Comp. Gen. 977 (1974).

12. NASA Procurement Directive 70-15, December 3, 1975, currently in effect.

13. *Supra* note 8.

14. *Supra* note 11.

15. Comp. Gen. Dec. B-173677 (2), March 31, 1972; summarized in 51 Comp. Gen. 621 (1972).

16. *Id.* at 622.

17. *See*, 54 Comp. Gen. 60 (1974); *cf.* 5? Comp. Gen. 117 (1972).

18. 55 Comp. Gen. 802, 807 (1976).

19. 54 Comp. Gen. 408 (1974).

20. *Id.*, at 411.

21. Comp. Gen. Dec. B-179030, Jan. 24, 1974.

22. *Supra* note 8.

23. *Id.*

24. *See* 56 Comp. Gen. 989 (1977); 51 Comp. Gen. 621 (1972); *cf.* 54 Comp. Gen. 562, 570, 571 (1975); *aff'd*, 54 Comp. Gen. 1009 (1975).

25. *Supra* note 9.

26. *Supra* note 3.

27. *Supra* note 9.

28. *See generally*, Comp. Gen. Dec. B-181075, Oct. 30, 1974; *see also* Comp. Gen Dec. B-178567, Dec. 14, 1973.

29. 50 Comp. Gen. 739 (1971).

30. 54 Comp. Gen. 352 (1974).

31. *Id.*, *see*, Comp. Gen. Dec. B-179030, Jan. 24, 1974.

32. *Supra* note 9.

33. *Id.*

34. *Id.*

35. Comp. Gen. Dec. B-182558, March 24, 1975.

36. 53 Comp. Gen. 240, 247 (1973); 53 Comp. Gen. 977, 1032 (1974).

37. 52 Comp. Gen. 870, 871 (1973).

38. 54 Comp. Gen. 408, 411 (1974).

39. ASPR 4-102 (1976 edition).

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A NEW LOOK AT CONTRACTORS' PAST PERFORMANCE

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BACKGROUND

The concept of rewarding and/or penalizing defense contractors based on their past performance is certainly not new. Hitch and McKean identified its importance in 1960:

> ...Nothing spurs a contractor as effectively as knowledge that his performance will be compared directly with that of a rival or rivals, with appropriate rewards and penalties--either in the short run (by the terms of the current contract) or the somewhat longer run (in the next or later contracts). (7:232-233)

Frederick M. Scherer thoroughly explored the concept of competition based on contractor reputation and identified numerous difficulties with such a system including the problem of time, quality, and cost weighting; the difficulty of measurement without the influence of biases; and the problem of blending good and poor jobs together to obtain an overall index of contractor performance. (10:68-101)

Today's Armed Services Procurement Regulation (ASPR) states that ".... the Contracting Officer shall consider not only technical competence, but also all other pertinent factors including management capabilities, cost controls, and past performance in adhering to contract requirements, weighing each factor in accordance with the requirements of the particular procurement..." (underscoring supplied). (3:1-903.1(iii))

The Air Force regulation on source selection outlines a separate section on "Offerors' Past Performance" as part of the Source Selection Advisory Council Analysis Report (2:A-4); and until recently the weighted guidelines method of the ASPR included a factor for contractors' past performance in computing the profit or fee objective. (8:23)

Despite this apparent recognition of the importance of a contractor's historical performance, the Department of Defense currently displays scant evidence of placing meaningful emphasis in this area. It is not uncommon to find a case in which a company has received a very desirable new program award after completing an essentially unsatisfactory performance.

This situation is in stark contrast to that of the private sector where organizations generally maintain a list of preferred vendors and suppliers. The "preferred list" is primarily determind by experience from previous contracts and frequently is the major influence in the determination of future awards. (5:303-304)

Competition in the defense marketplace is such that contractors give top priority to moving into promising new fields and thereby promoting capabilities for winning future programs. Achieving good performance on current programs becomes of secondary importance. Unfortunately, there is no concerted program in the Department of Defense to effectively counter this condition.

Thus, today's source selection authority (SSA) is missing an important and powerful tool for forming his selection decision. Although he may be presented with some subjective and sketchy information on past performance, it generally is lacking in comparable depth or consistency.

LESSONS OF THE PAST

What can be done to rescue the source selection authority from this dearth of meaningful past performance data? Since the problem is not a new one, there is ample information from the past which bears examination.

In the 1960's the Department of Defense developed considerable experience with its Contractor Performance Evaluation (CPE) system. The system encompassed R&D programs of $2M per year or $10M overall and production programs of $10M per year or $20M overall. (1:VI-4) The CPE system required a total of eight DOD forms to be completed on a semi-annual basis by project managers, service evaluation groups, and contractors. (Figure 1) (1:VI 18-43)

CPE DOCUMENTATION	
DD Forms	Subject
1446	Contract Brief (Description)
1446-1	Technical Performance
1446-2	Schedule Performance
1446-3	Cost Performance
1446-4	Narrative
1446-5	Contractor's Comments
1447	Departmental CPE Group Report
1447 c	Continuation Sheet

FIGURE 1

The submission and review process for these forms was quite extensive (Figure 2) prior to being forwarded to the DOD Data Bank at the Defense Documentation Center for future use by source selection organizations, contracting officers and the renegotiation board. (1:VI-4-9)

When it was initiated in 1963, the CPE program was designed to be fact-oriented to the maximum extent possible. There was provision, however, for judgmental comments by both the project manager and the contractor. This aspect of the program allowed it to degenerate into one of verbal duels between project offices and contractors whenever honest differences of opinion arose. (8:34-35)

A survey conducted in 1967 by Air Force Systems Command found that CPE data was being used in varying degrees by source selection advisory councils but there was only one instance where it proved to be a decisive factor in contract award. (8:37-38) Thus there was no firm evidence that the program was achieving its prime objective despite years of operation and extensive involvement of both government and contractor personnel.

In November of 1970 the program was formally canceled as not being cost effective or useful for source selection. Its sophistication and the volume of paper which it generated, helped lead to its demise. A prime cause, however, was its failure to employ a methodology for consistent use of the data by source selection authorities and contracting officers.

Experience from the CPE of the 1960's points to the fact that a successful program of the future must emphasize simplicity and the prime elements of cost, schedule and technical performance. Subjective narrative assessments should be avoided and a consistent methodology for utilization must be developed, enforced, and continuously tracked to determine its effectiveness.

PROPOSED CONTRACTOR PERFORMANCE PROGRAM

There is still a need for a structured program to measure and take into account a contractor's past performance. Few dispute that past performance should be considered somewhere in the source selection process. Diverse opinions exist, however, as to the type of information required and the manner in which it should be employed.

The author is proposing a simplified, fact-oriented data system that records the cost, schedule and performance status of major Department of Defense contracts that have been active in recent years. Included is a suggestion on how this information can be used by source selection activities.

Initially it is recommended that the information be accumulated on Department of Defense contracts over $5M which are currently active or which have been completed during the past three years. The data generated would be succinct and broken into four areas: (1)administrative, (2) cost, (3) schedule, and (4) performance:

Administrative - A listing of the contract number; dollar value, procuring agency; acquisition phase (advanced development, production, etc.); brief description of work; names and telephone numbers of government project manager, PCO, and ACO; dates of contract; and type of contract.

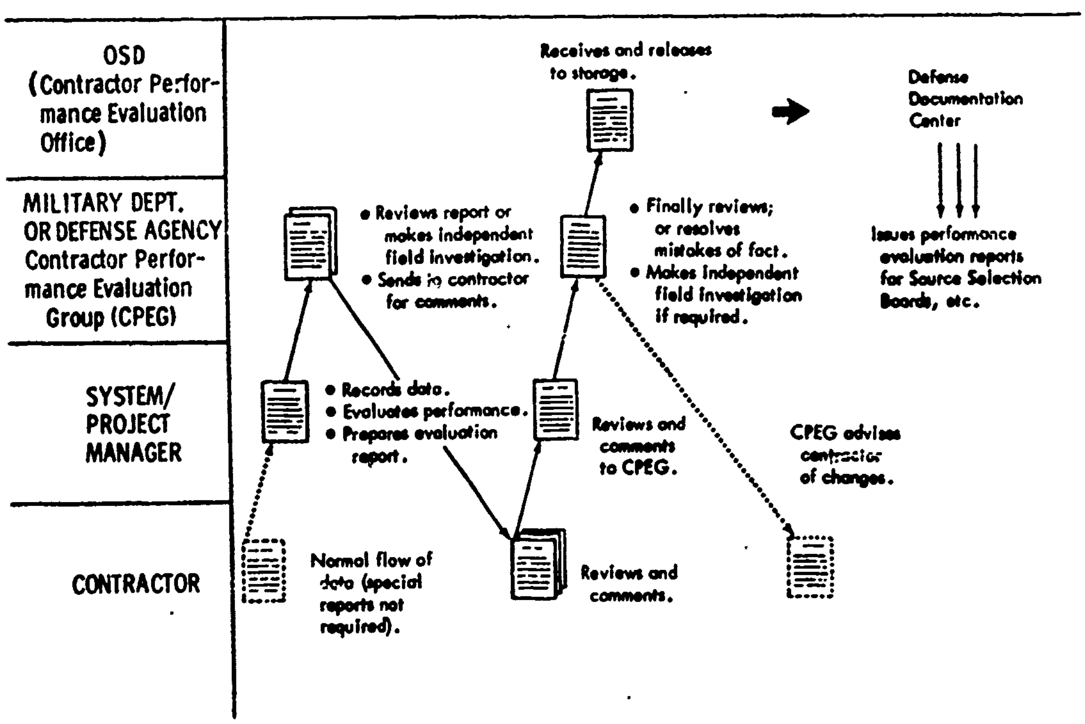
Cost - Per cent over or under target and dollar amount (actual for completed and estimated at completion for active contracts). Number and dollar amounts of claims submitted and claims approved/disapproved.

FIGURE 2

FORMER DOD SYSTEM FOR EVALUATION

OF A

CONTRACTOR'S PERFORMANCE



Schedule - Months the contract has been delinquent/total contract months. Reasons for delinquencies. Changes made to original schedule and reasons.

Performance - Number of DD 250 acceptances; numbers of major deficiencies and conditional acceptances on DD 250's. Numbers of deviations and waivers. Numbers of specifications and test plans/reports resubmitted for approval. (Figure 3)

DATA COLLECTION

The proposed information can be gathered in a number of ways. The author suggests that it be maintained by administrative contracting officers and be updated as required in order to be submitted to procuring agencies in conjunction with contractor proposals. It is important that the contractor's most recent experience is included,as recently ruled by the General Accounting Office (GAO) (6:A-7). Until a DOD-wide system or requirement is established, requests for proposals can solicit the desired information from offerors and this data can be validated in preaward surveys. The mere fact that such information is being requested from offerors will serve to put them on notice that the Department of Defense is giving added emphasis to contractors' past performance.

Air Force Systems Command (AFSC) already has a computerized procurement information program, the Automated Management Information System (AMIS), which can possibly be tapped to add the above data on contractor performance. An addition to the current AMIS could be made so that the information would be continuously and immediately available to all organizations in AFSC. Since the Defense Logistics Agency will be exchanging procurement information with AMIS, needed information could be included on all contracts administered by the Defense Contract Administration Service (DCAS).

UTILIZATION IN SOURCE SELECTION

The method and form in which this information is used can be standardized to a simple, basic report for presentation to source selection authorities. The cost information would reflect the number of contracts which met or were over or under target costs. Schedule information would reflect total months of original contracts and the number of months delinquent and/or of schedule extension, and the technical performance portion would reflect the quality of the products delivered by indicating the number of deviations, conditional acceptances, etc. on a percentage basis relative to the total items delivered. Dollar values would be totaled to show gross overrun/underrun for the total contracts charted. Examples of summary charts which might be developed for source selection purposes are shown in Figures 4 and 5.

Since standardized incorporation of such information in the source selection process will constitute a new emphasis on past performance, requests for proposals must clearly state the manner in which past performance will be considered as part of the criteria for contract award. In the event a contractor has not performed on previous Department of Defense contracts, it can be stated that information relative to performance on comparable non-DOD contracts may be requested. In any event, it should not be implied nor intended that data contained in any computerized data bank will constitute the sum total of all past performance information to be considered by the source selection authority. Other pertinent factual information such as that which might be gathered from contact with program managers or contracting personnel, can and should be made available for the SSA's consideration.

The person or persons who consolidate the past performance information for presentation to the SSA must be cognizant of serving a role of collation and summarization, not one of evaluation. If additional information is gathered on one prospective contractor, then comparable information should be gathered on all others.

Since the prime objective of the program is to influence source selection, a feedback system is required to continuously evaluate whether past performance information is actually playing a role in source selection decisions. A survey form to be completed by source selection authorities and/or PCO's, could provide the information desired regarding effectiveness of the program.

FIGURE 3

ADMINISTRATIVE
Contract Number:
Dollar Value:
Procuring Agency:
Acquisition Phase: (Development or Production)
Brief Description of Work:
Name and Telephone No. of: Government Program/Project Manager:
PCO:
ACO:
Dates of Contract:
Type of Contract (e.g. FFP, CPIF, etc.):

COST (FOR CPIF, CPFF, FPIF, FPIS)
PER CENT over or under target (actual for completed contracts and MEAC for active contracts):
Dollar Amount over or under target:
Number and Dollar Amounts of claims submitted:
Number and Dollar Amounts of claims disapproved:

SCHEDULE
Number of months contract was/has been delinquent and reason(s):
Per cent of months contract was in delinquent status (i.e. total months delinquent divided by total contract months):
Number of times original schedule has been changed, by how much, and reasons for change:

PERFORMANCE
Number of DD 250 Acceptances:
Number of Major Deficiencies/Conditional Acceptances on DD 250's:
Number of Deviations Granted:
Number of Waivers Granted:
Number of Test Plans and Reports Submitted for Approval:
Number Submitted Late:
Number of Test Plans and Reports Resubmitted for Approval:
Number of Specifications Submitted for Approval:
Number Submitted Late:
Number of Specifications Resubmitted for Approval:

FIGURE 4

CONTRACTOR XYZ

NO. OF DEVELOPMENT CONTRACTS: 12 (7 COMPLETE, 5 ACTIVE)

TOTAL DOLLAR VALVE: $213M

COST	SCHEDULE
CONTRACTS OVER TARGET: 10	TOTAL CONTRACT MONTHS: 210
CONTRACTS UNDER TARGET: 2	MONTHS CONTRACTS DELINQUENT: 19 (9%)
GROSS PER CENT OVER/UNDER TARGET COSTS: 8% (17M) OVER	MONTHS OF SCHEDULE CHANGE DUE TO NONPERFORMANCE: 22

PERFORMANCE
NO. OF DELIVERABLE ITEMS: 93
NO. OF DEVIATIONS AND WAIVERS: 34
NO. OF MAJOR DEFICIENCIES ON ORIGINAL ACCEPTANCE INSPECTIONS: 7
NO. OF CONDITIONAL ACCEPTANCES: 14
TEST PLANS/SPECIFICATIONS SUBMITTED LATE: 25/300 = 8.3%
TEST PLANS/SPECIFICATIONS DISAPPROVED: 33/300 = 11%

FIGURE 5

ABC COMPANY
COST PERFORMANCE (IN MILLIONS)
DEVELOPMENT

PROGRAM	TARGET COST	ACTUAL / ESTIMATE AT COMPLETION	OVER / (UNDER) TARGET COST	OVER / (UNDER) PERCENT
A-I RADAR	70	81	11	15.7%
• B-2 MISSILE	32	48	16	50%
C-3 POD	30	40	10	33%
D-4 NAVIGATION SYS.	12.6	11.9	(0.7)	(5.6%)
• E-5 JAMMER	7.2	7.8	0.6	8.3%

• COMPLETED PROGRAMS

CONCLUSIONS

The purpose of source selection is to select a contractor, not merely to choose between competing proposals. Yet the emphasis in most Department of Defense source selections is overwhelmingly upon the evaluation of technical proposals. The difference between contractors is seldom illuminated as articulately as are the differences between their proposals.

A practical reporting system on contractors' past performance is urgently needed in order to consider past as well as proposed performance when selecting DOD contractors. A system is proposed which will provide factual data to source selection groups and which will not require the generation of complicated or sophisticated information which might cause expenditure of inordinate man-hours. At a later date it may be desirable to develop performance indices in each of the three areas of cost, schedule and performance.

It is recommended that the proposed system be initiated at a division within Air Force Ststems Command. The Electronic Systems Division at Hanscom AFB, Massachusetts has already taken actions to include such information in the source selection process and HQ AFSC has recently issued a policy letter requiring past performance consideration for source selection. Since this rejuvenated concept has significant implications for the defense industry overall, recommend it be presented to the Council of Defense and Space Industries Association (CODSIA) for their review and comments.

In the latter part of 1978 a "debugged" and coordinated program can be expanded to all of Air Force Systems Command with subsequent adoption by the entire Department of Defense. With a positive determination by management and with an open mind by those who must implement such a program, we can take a giant step towards improving the relationship between past performance and future awards.

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SENSITIVITY OF OFFERORS' SCORES TO VARIATIONS IN ITEM WEIGHTS AND ITEM SCORES

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INTRODUCTION

Numerical scoring of offeror's proposals in accordance with AFLC Supplement I (16 February 1977) to AFR 70-15 (16 April 1976) is carried out in the following way: before proposals are received, the Source Selection Advisory Council (SSAC) identifies key areas most significant for the success of the program, and determines the relative importance of each area. The SSAC also makes shredouts of significant items in each area. The SSAC allots numerical weights to each item of each area, subject to the requirements that the sum of all the weights will equal 1000, that the sum of the weights assigned to each area will reflect the relative importance of that area, and that the item weights will reflect the relative importance of each item within an area. When proposals are received, the Source Selection Evaluation Board (SSEB) assigns a score to each proposal, on each item. These item scores range from 0 to 1 and reflect the fraction of the weight allotted to each item earned by the offeror's response. SSEB members do not know values of the weights assigned by the SSAC. An offeror's total score is then computed as the sum of the products of the item scores with the corresponding weights. The scoring and weighting example given in AFLC Supplement I to AFR 70-15 is shown in Table I.

When the numerical scoring and weighting is completed, offerors' proposals are compared (ranked or ordered) by comparing their total scores. This brings up the question of the sensitivity of the total scores to small variations in the choices of item weights, and to small variations in item scores. In particular, one would like to know whether such variations could cause offeror A to have a greater total score than offeror B in one case, while making B's score exceed A's in another. The question is not entirely trivial, because the requirements of AFR 70-15 and AFLC Supplement I thereto restrict the choice of weights. In this paper we show that, while small relative variations in weights or scores may indeed reverse the ranking of two offerors' total scores, there are fairly simple, commonsensical tests which identify rankings that cannot be overturned by relatively small changes in item weights or item scores.

Let us begin by describing the scoring and weighting procedure quantitatively. This can be done by the equations and inequalities

$$S = \sum_{i=1}^{N} \sum_{j=1}^{M_i} s_j^i w_j^i \tag{1}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{M_i} w_j^i = 1000 \tag{2}$$

	SSEB Scoring			SSAC Weighting	
	Points Possible	Points Assigned	Percentage Score	Weight Allotted	Weighted Score
(Area 1)					
Item 1	10	2	.20	75	15.0
Item 2	10	5	.50	125	62.5
Item 3	10	3	.30	100	30.0
Item 4	10	4	.40	150	60.0
Item 5	10	4	.40	50	20.0
Area Total:				500	187.5
(Area 2)					
Item 1	10	9	.90	75	67.5
Item 2	10	8	.80	25	20.0
Item 3	10	4	.40	100	40.0
Area Total:				200	127.5
(Area 3)					
Item 1	10	10	1.00	100	100
Item 2	10	7	.70	80	56
Area Total:				180	156
(Area 4)					
Item 1	10	8	.80	120	96
Area Total:				120	96
TOTAL				1000	567

Table 1

$$\sum_{j=1}^{M_1} w_j^1 > \sum_{j=1}^{M_2} w_j^2 > \ldots > \sum_{j=1}^{M_N} w_j^N \qquad (3)$$

$$w_1^i > w_2^i > \ldots > w_{M_i}^i, \; i = 1,\ldots,N \qquad (4)$$

$$0 \le s_j^i \le 1 \qquad (5)$$

In equations (1) and (2), S is the total score, N is the number of areas identified by the SSAC, M_i the number of items associated with the i^{th} area, s_j^i is the offeror's score on item j of area i, and w_j^i is the weight assigned to item j of area i. Equation (1) gives the procedure for computing an offeror's total score. Equation (2) expresses the requirement that the weights add up to 1000, and inequalities (3) express the requirement that the total of the weights assigned to each area reflects the predetermined relative importance of that area. Inequalities (4) state that the item weights reflect the relative importance of the items within an area, a l inequalities (5) specify the convention that item scores range from 0 through 1.

Now, let's consider the question of whether offeror's rankings can be overturned by relatively small changes in item weights, for fixed item scores. We work with two offerors, A and B. Let A's item scores be a_j^i, and denote B's item scores by b_j^i. Then A's total score S_A, and B's total score S_B, are given by

$$S_A = \sum_{i=1}^{N} \sum_{j=1}^{M_i} a_j^i w_j^i, \; S_B = \sum_{i=1}^{N} \sum_{j=1}^{M_i} b_j^i w_j^i \qquad (6)$$

We can simplify our work considerably, and still answer the question of interest, by considering a restricted case, in which all the item weights except w_1^1 and w_2^1 are kept fixed, and in which A and B have the same item scores except for a_1^1, a_2^1 and b_1^1, b_2^1. Then

$$S_A = a_1^1 w_1^1 + a_2^1 w_2^1 + Q,$$

$$S_B = b_1^1 w_1^1 + b_2^1 w_2^1 + Q \qquad (7)$$

where

$$Q = \sum_{i=2}^{N} \sum_{j=1}^{M_i} a_j^i w_j^i + \sum_{j=3}^{M_1} a_j^1 w_j^1, \qquad (8)$$

so that the rank of S_A and S_B will be determined solely by the partial scores T_A and T_B where

$$T_A \equiv a_1 w_1 + a_2 w_2, \; T_B \equiv b_1 w_1 + b_2 w_2 \qquad (9)$$

That is, A ranks ahead of B if $T_A > T_B$, and conversely.* Now, we ask our question in this restricted setting. That is, is it possible that, given fixed a_1, a_2 and b_1, b_2, there exist admissible choices of w_1 and w_2 which differ relatively little, such that for one choice $T_A > T_B$, while for the other, $T_B > T_A$? We'll find such choices below, and, since our restricted case is a valid particular case of the general question, the question will be answered, yes.

In order to meet (2) with all weights except w_1 and w_2 fixed, we may vary w_1 and w_2 only while keeping their sum constant. That is, we must have

$$w_1 + w_2 = K = 1000 - \sum_{i=2}^{N} \sum_{j=1}^{M_i} w_j^i - \sum_{j=3}^{M_1} w_j^1 \qquad (10)$$

To preserve the relative importance inequality (4), we must have

$$w_1 > w_2 > w_3^1 \qquad (11)$$

A principal reason for going to this present "two-dimensional restriction" is that pictures can now be made to illustrate our proceedings. In particular, relations (10) and (11) may be graphed as in Fig. 1:

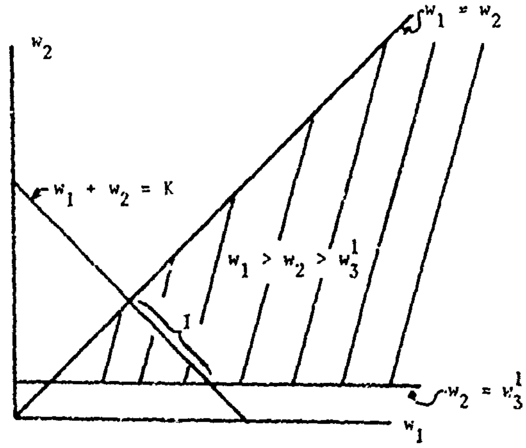

Figure 1

*In (9) and in the following, the common superscript "1" is omitted from w_1^1 and w_2^1 for clarity in writing

Figure 1 shows that we are free to vary w_1 and w_2 along the interval I of the line $w_1 + w_2 = K$. That is, any choice of w_1 and w_2 on this line will, taken together with the fixed weights, meet (2), (3) and (4).

Now, let us ask, "what condition must hold, if $T_A = T_B$?" In that event, we must have

$$w_1a_1 + w_2a_2 = w_1b_1 + w_2b_2, \text{ or}$$

$$w_1(a_1-b_1) + w_2(a_2-b_2) = 0 \qquad (12)$$

Now, (12) is the equation of a straight line in the w_1 - w_2 plane. This is the line $T_A = T_B$. On one side of this line, $T_A > T_B$; on the other, $T_A < T_B$. Thus: If the straight line (12) intersects I, then there will be admissible choices of w_1 and w_2, for some of which $T_A > T_B$, and for some of which $T_A < T_B$.

Actually, it is easy to write a condition on a_1, a_2, b_1 and b_2 such that the intersection occurs. Straightforward analysis shows that the intersection does occur, provided

$$\frac{w_3^1}{K - w_3^1} < \frac{b_1 - a_1}{a_2 - b_2} < 1. \qquad (13)$$

Whenever (13) is met, the complete picture of the situation is shown in Figure 2:

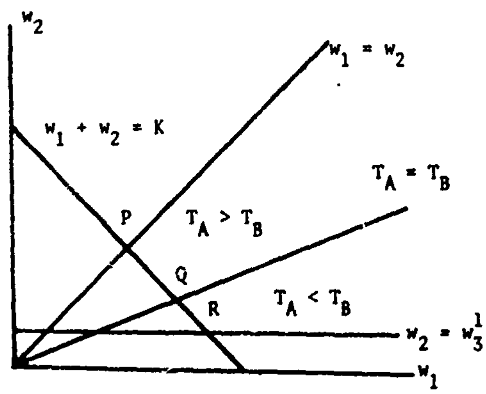

Figure 2

For w_1 and w_2 on segment PQ, $T_A > T_B$; for w_1 and w_2 on QR, $T_A < T_B$.

Actually, since $w_1 > w_2$ and $w_2 > w_3^1$ and $w_1 + w_2 = K$, $w_3^1 < K/2$, so that $w_3^1/(K-w_3^1) < 1$, always. Thus (13) can <u>always</u> be met for <u>some</u> choice of a_1, b_1, a_2, b_2.

SPECIFIC EXAMPLE

Suppose that all the item weights except w_1, w_2, and w_3^1 add up to 650, and that $w_3^1 = 50$. Then K = 300, and (10) and (11) take the forms

$$w_1 + w_2 = 300. \qquad (14)$$

and

$$w_1 > w_2 > 50 \qquad (15)$$

Inequalities (13) become

$$\frac{1}{5} < \frac{b_1 - a_1}{a_2 - b_2} < 1. \qquad (16)$$

A choice of factor scores which satisfies (16) is:

$$a_1 = .6 \qquad b_1 = .9$$

$$a_2 = .9 \qquad b_2 = .4 \qquad (17)$$

Two choices of weights which satisfy (14) and (15) are:

Case I. $w_1 = 200$, $w_2 = 100$ (18)

Case II. $w_1 = 180$, $w_2 = 120$ (19)

For the item scores of (17) and the weights of Case I, $T_A = 210$, $T_B = 220$, so that offeror B ranks ahead of offeror A. But for these same item scores, the weights of Case II lead to $T_A = 216$, $T_B = 210$, so that offeror A ranks ahead of offeror B. The weights of Cases I and II differ from their means by 5% for w_1, and by 9% for w_2. Thus, it is true that relatively small changes in item weights can change offeror's rankings for given item scores.

FIXED WEIGHTS AND VARYING FACTOR SCORES

This case is much simpler than the previous one, because the conditions (5) which item scores must meet are much simpler than conditions (2), (3), and (4) on the item weights. To see that indeed, relatively small changes in item scores can overturn offeror's rankings, consider the case of offeror A and offeror B,

with identical item scores except for the first two items of area 1. Let A's and B's scores on those items be the ones given in (17), and let the weights for these items be those of Case I (equation (18)). Then B's total score exceeds A's by 10 points. If then B's scores are each reduced by 10%, and A's increased by 10%, A's total score exceeds B's by 33 points.

A DOSE OF COMMON SENSE

Actually, there are straightforward, common-sensical rules which give firm guarantees that certain rankings cannot be overturned by relatively small changes in item weights, item scores, or both. Very likely, the rules are already applied routinely, as a matter of good judgement. They are simple to describe:

Rule 1: The ranking of two offerors whose total scores differ by an amount which is greater than P% of their sum, cannot be overturned by changes in weights for which the greatest relative change does not exceed P%.

Rule 2: The ranking of two offerors whose total scores differ by an amount which is greater than P% of their sum cannot be overturned by changes in factor scores for which the greatest relative change does not exceed P%.

Rule 3: The ranking of two offerors whose total scores differ by more than the product of the factor $\frac{P}{100}\left(\frac{P}{100}+2\right)$ and their sum, cannot be overturned by any combination of changes in item weights and item scores, for which the greatest relative change does not exceed P%.

All these rules follow from one fairly straightforward calculation. If weight w_j^i is changed by an amount δw_j^i, and item score s_j^i is changed by an amount δs_j^i, then total score S will change to the value $S + \delta s$, where

$$S + \delta S = \sum_{i=1}^{N}\sum_{j=1}^{M_i}(s_j^i + \delta s_j^i)(w_j^i + \delta w_j^i)$$

$$= S + \sum_{i=1}^{N}\sum_{j=1}^{M_i}[s_j^i\delta w_j^i + \delta s_j^i w_j^i + \delta s_j^i \delta w_j^i], \quad (20)$$

so that

$$\delta S = \sum_{i=1}^{N}\sum_{j=1}^{M_i}[s_j^i\delta w_j^i + \delta s_j^i w_j^i + \delta s_j^i \delta w_j^i] \quad (21)$$

We may re-write (21) as

$$\delta S = \sum_{i=1}^{N}\sum_{j=1}^{M_i}\left[s_j^i w_j^i\left|\frac{\delta w_j^i}{w_j^i}\right| + s_j^i w_j^i\left|\frac{\delta s_j^i}{s_j^i}\right| + s_j^i w_j^i\left|\frac{\delta s_j^i}{s_j^i}\right|\left|\frac{\delta w_j^i}{w_j^i}\right|\right].$$

Since the magnitude of a sum does not exceed the sum of the magnitudes of its terms,

$$|\delta S| \le \sum_{i=1}^{N}\sum_{j=1}^{M_i}\left[s_j^i w_j^i\left|\frac{\delta w_j^i}{w_j^i}\right| + s_j^i w_j^i\left|\frac{\delta s_j^i}{s_j^i}\right| + s_j^i w_j^i\left|\frac{\delta s_j^i}{s_j^i}\right|\left|\frac{\delta w_j^i}{w_j^i}\right|\right] \quad (22)$$

In (22), the fact that all s_j^i and w_j^i are positive has been used.

Now, a sum is not decreased if each of its terms is either made algebraically larger or left the same. Therefore

$$\sum_{i=1}^{N}\sum_{j=1}^{M_i} s_j^i w_j^i\left|\frac{\delta w_j^i}{w_j^i}\right| \le \sum_{i=1}^{N}\sum_{j=1}^{M_i} s_j^i w_j^i \max_{i,j}\left|\frac{\delta w_j^i}{w_j^i}\right|$$

$$= \max_{i,j}\left|\frac{\delta w_j^i}{w_j^i}\right| \sum_{i=1}^{N}\sum_{j=1}^{M_i} s_j^i w_j^i$$

$$= \max_{i,j}\left|\frac{\delta w_j^i}{w_j^i}\right| \cdot S. \quad (23)$$

Similar arguments hold for each term of (22), so that, defining

$$||\delta s|| \equiv \max_{i,j}\left|\frac{\delta s_j^i}{s_j^i}\right| \quad (24)$$

$$||\delta w|| \equiv \max_{i,j}\left|\frac{\delta w_j^i}{w_j^i}\right| \quad (25)$$

we have

$$|\delta s| \le ||\delta w||\cdot S + ||\delta s||\cdot S + ||\delta w||\cdot||\delta s||\cdot S,$$

and $\frac{|\delta S|}{S}$, the relative change in S, is bounded by

$$\frac{|\delta S|}{S} < ||\delta w|| + ||\delta s|| + ||\delta w||\cdot||\delta s|| \quad (26)$$

Rules (1), (2), and (3) are immediate consequences of (26). For example, if only the item

weights are changed, $||\delta s||$ will be zero, and

$$\frac{|\delta S|}{S} \le ||\delta w||$$

If then original offerors' total scores are S_u and S_L, with $S_u > S_L$, under change of weight S_u cannot be reduced to less than $S_u(1 - ||\delta w||)$, and S_L cannot be increased to more than $S_L(1 + ||\delta w||)$. Therefore the offerors' ranking can be overturned only if

$$S_L(1 + ||\delta w||) > S_u(1 - ||\delta w||),$$

which implies

$$S_u - S_L < ||\delta w||\cdot(S_u+S_L) \qquad (27)$$

Inequality (27) is, of course, a mathematical statement of Rule 1. Rule 2 follows exactly similarly, when $||\delta w||$ is taken to be zero. Rule 3 follows from the observation that, when both scores and weights fluctuate subject to the conditions

$$||\delta w|| < f,\ ||\delta s|| < f,$$

then

$$\frac{|\delta S|}{S} \le 2f + f^2 = f(f+2).$$

Then S_u cannot be reduced to less than $S_u(1 - f(f+2))$, while S_L cannot be increased to more than $S_L(1 - f(f+2))$, so that the offerors' ranking can be overturned only if

$$S_L(1 + f(f+2)) > S_u(1 - f(f+2)),$$

which implies

$$S_u - S_L < f(f+2)(S_u+S_L). \qquad (28)$$

Equation (28) is a statement of Rule 3.

CONCLUSION

The order of numerical scores of proposals can be overturned by small relative changes in item weights and item scores whenever differences between scores are small fractions of the scores, even when item weights meet all the requirements of AFR 70-15 and AFLC Supplement I to that regulation. However, as specified in Rules (1), (2), and (3) above, when differences between offeror's total scores are not small fractions of the scores, the order of scores cannot be overturned by small relative changes in item weights and scores.

ACKNOWLEDGEMENT

It is a pleasure to acknowledge stimulating conversations with Captain William L. Glover, who brought the subject to the author's attention.

POTPOURRI

THE FUNCTIONAL VALUE OF UNCERTAINTY IN THE PROCUREMENT PROCESS

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INTRODUCTION

Where the performance (or product) requirements of the end product or service are completely specified (and the means of verification are easily available, and where time and cost estimates are reasonably related, the procuring agency can have reasonable confidence in beginning the procuring process. If one or more bidders are able to reasonably estimate the costs and time related to providing the specified product or service, the potential for a successful procurement appears to be reasonably good.

In contrast, where performance (or product) requirements are subject to significant uncertainty, where the time and cost to provide are uncertain, and where means of verification are difficult or uncertain, the cumulative effect of all of these uncertainties is usually considered to present considerable problems in the procurement process, and a wide variety of methods have been developed by both procuring agencies and contractors to solve these problems.

Research to improve our understanding of the relationship between a specific method and a desired result (or to improve our ability to achieve a desired result) takes many forms but may be characterized by two major dichotomies: first, the difference in approach (and purpose) between the practitioner and the researcher, and, second, the difference in approach between those who use verbal (usually, behavioral) models and those who use mathematical ("quantitative") models. These differences not only limit cooperative approaches to shared problems, but also limit the ability and willingness to draw upon solutions developed by the "other" group [34]. These differences are often expressed in terms of credibility (lack of rigor) and usefulness (lack of relevance).

Drawing upon specific experience with a wide variety of procurement practices and research on the procurement process, the characteristic commonly identified as "uncertainty" is used to analyse a set of illustrative problems and how various solution methods are designed to deal with problems. Graphical models (in the general form of those familiar in systems analysis and production control) will be used to provide a common language bridging the two dichotomies and as an analytical tool for describing specific procurement problems from the point of view of both the buyer and the seller.

It is proposed that "uncertainty" provides a relatively stable and ubiquitous dimension for analyzing a great variety of problems and methods, and that graphical models provide a useful common language.

UNCERTAINTY AS A PROBLEM

Uncertainty, and the related concept of utility have long been subject to examination (see, for example, [12] [35]), but it is not the intent of this paper to review the extensive writings in this field. The brief comments in this section are intended to provide some general sense of the use of the term, to reference selected examples of its use in the engineering literature, to note the sequential characteristic of the process of reducing uncertainty, and to reference its standing as a problem, and to identify characteristic solutions, in defense procurement.

Uncertainty is used here in its common sense, everyday meaning of how sure one is about something. It requires the identification of (or association with) a specific person (or persons), and the term "decision maker" is often used to identify the person. Conventionally, uncertainty may described in terms of probability ranging from 0.0 to 1.0, and this may be with respect to a particular relationship between one estimate and the object (referent) being estimated, or may be distributed over a range of estimates. Uncertainty may be described as one's confidence in the (or a specified) relationship between any two events (or objects or states).

Uncertainty has been the focus of concern in the management literature [7:2,7] [26] [37] and, particularly, in the engineering literature. For example, a quick search of recent issues of one journal discloses a variety of articles concerned with the information processes used to reduce uncertainty [4] [9] [15]. The engineering process has been characterized as a process for reducing uncertainty [14] [19], and as an early step in a sequential process of reducing uncertainty which extends through development to production [24] and sales [31] and use [3:18,21].

The problems presented in the procurement process are reflected in the wide variety of solutions proposed, only a sample of which will be referenced here. In the pre-award stages, various methods, such as briefing and the preparation of elaborate requests for proposals, are used as a prelude to equally elaborate judgmental processes for choosing contractors. Basic choices concerning the form of contract [10] [11] [21:15-16], use of parallel development [1], dividing a procurement

into phases, incorporation of specifications, and standards, and use of techniques such as design to cost and life cycle costing [16] [36:25] all reflect approaches to dealing with uncertainty. During the life of the contract, various process control methods are used, particularly with respect to management and cost control [8] [20] [22] [28]; and testing provides a major contribution to the reduction of uncertainty [18]. Concern with uncertainty during the use life of the procured product is reflected in provisions for warranties and guarantees, and programmatic requirements directed to reliability and maintainability [27]. Central to most, if not all, of these methods is the intent to minimize or control the risk to one or both parties arising out of uncertainty, including the preassignment of the risk to one of the parties [29:737]. And a concomitant element is often an increase in the adversary character of the relationship [25].

THE USEFULNESS OF UNCERTAINTY

As a practical matter, uncertainty is often a "good" thing. Most sporting events and games of skill (or chance) would lose their interest to participants and spectators (at least, some) if there were no element of uncertainty. On a personal basis, it is likely that few individuals would want to know, with certainty, the exact time they will die, or know exactly what others think of them. Even responsible senior decision makers may find it to be "good" to be uncertain, to be better off if they didn't know, e.g., Eisenhower and the U-2, and more recent presidential cases.

For those cases where uncertainty is not desired, it is important to distinguish between those cases where you can't do anything about it (with respect to current decisions) and those where you can. And what you can do is a function of identifying the particular decision maker, the point in time that the decision is to be made [5:2], what specific type of uncertainty is involved, and how he is likely to respond to it. For example, before award, the bidder is concerned with the uncertainty that he will win and his uncertainty in the relationship between his proposal terms and the performance he will have to provide; comparably, the government will be concerned with identifying the "best" bidder and the same uncertainty between proposal terms and performance. The contractor doesn't want to lose money (or reputation), and the government doesn't want to pay more than it has to (and should be equally concerned, in most cases, with paying less than the performance is worth) [25:59].

EXAMPLES

The examples to be presented in this section were chosen to illustrate the usefulness of an explicit recognition of the characteristics of the specific uncertainty presented in a particular procurement situation. There are, of course, many other possible illustrations, and variations on those presented. It should also be noted that the accompanying figures are intended only to illustrate the particular situation and are in the form of rough sketches; all of the curves are intended to be approximations to a normal distribution. In the interest of simplification, a minimum number of cases are presented in an example, and it should be noted that the scales are sometimes compressed.

Shared High Uncertainty

Particularly in the early stages of the development of a new capability both the government and prospective bidders share a high degree of uncertainty concerning not only the cost but also the time required and the level of performance (achievable and/or required). Where there is a high degree of uncertainty, it is likely that the estimates (of cost, time, or performance) made by different decision makers (bidders) may overlap considerably. This is illustrated in Figure 1. Estimates by bidders A, B, and C, while different, overlap to a considerable extent; and, if the government's uncertainty is comparable, its estimates may also overlap, unless biased by reasons of differences in information available or other requirements imposed upon the estimating process. If each bidder were to use the average of his estimate, there would be the illustrated separation. However, the high uncertainty diminishes the predictive value of the average, presenting a range of reasonable variations. In the illustrated case, bidder A, for other reasons, chooses the low end, and his bid price is lowest even though his average is highest. Because these "other reasons" may not be related to what it will cost to perform, and, further, because the differences among the estimates themselves may not be related to differences in the cost to perform, it seems clear that the bid prices may be of little use in determining which bidder can produce for the lowest cost. The use of cost-type contracts reflects this mutual uncertainty, minimizing the risk to both government and contractor where the price is substantially lower or higher than the actual costs incurred; and, as a corollary, where the risk is lessened, both parties can concentrate on reducing uncertainty with respect to performance (and time), and cost is "controlled" by other, process based methods.

Where there is, in fact, a high degree of shared uncertainty, it would appear that a frank recognition would minimize a number of inappropriate behaviors. First, the govern-

ment should concentrate on other characteristics of the bidders (e.g., technical competence, effectiveness of cost management, long-term interest in the procurement) and give little or no weight to "low price." Second, both the contractor and the government should give high priority to early and progressive reestimating of cost (and performance and time), and the budgeting and review processes should recognize that the terms "overrun" and "slippage" are inappropriate.

Uncertainty Over Time

One of the characteristics of most estimates is that they increase in uncertainty as they are extended forward in time. This is illustrated in the top part of Figure 2. As was true in the first example, this is a type of uncertainty which we can do little about directly except to recognize it. If a procurement covers an extended period of time, both the bidders and the government are forced to combine relatively good estimates for near future activities with progressively poorer estimates of future activities. The conventional solution is to divide the procurement into successive phases.

By dividing the procurement into phases, it is now possible to estimate the second phase at t_2 (see Figure 2, bottom part), taking advantage of the reduction in uncertainty resulting from the activities in the first phase, advances in the state-of-the-art elsewhere, reductions in uncertainty with respect to the specification of requirements and of related systems and components, and the increased familiarity, knowledge, and experience of both contractor and government with respect to the program [30:32].

It seems clear that, with this type of uncertainty, the estimates at t_1 with respect to later phases should be frankly recognized as high uncertainty, as was true in the first illustration [6:57].

Separating High and Low Uncertainty

In some cases a procurement will combine an activity or task which is of high uncertainty with another activity of low uncertainty. The bidder who is forced to aggregate these two activities is faced with a relatively high uncertainty estimate, and the result is that estimates of different bidders tend to overlap (see Figure 3, left hand side). This may occur in building construction where soil conditions and weather present high uncertainty while structural costs present much less uncertainty. Similarly, on procurements with elements in the far future, e.g., life cycle costing of energy using devices where future rates are uncertain, production costs may be relatively certain compared with those elements in the future.

Where the high uncertainty can be factored out, bidders may be able to limit their cost estimates to the low uncertainty part with the result that real differences in bid price will appear (see Figure 3, right hand side).

In the case of life cycle costs for energy using devices, usage levels and rates can be specified for bidding purposes; in this case, uncertainty is reduced for the bidders, with the government absorbing the uncertainty. Similarly, separate provisions may be made for soil conditions, weather, inflation, and other conditions not under the control of the parties.

There is a special case where the uncertainty with respect to a specific element is so high that it may not be possible to accomplish at all. If the element is necessary, and if it can be worked on out of sequence, the government should require that the contractor work on it first. Thus, if the element turns out to be impossible to accomplish, the government can save the cost of developing the other elements.

Differences in Uncertainty Among Bidders

In some cases one bidder will have considerably less uncertainty than other bidders; this may be because he was the original development or production contractor, or he may have more background and experience in the area. This is illustrated in Figure 4, left hand side. Bidders A and C are in the same position as the bidders in the first example; if they bid low and win, they may be faced with either losing money or cutting corners or trying to get changes. If they bid high, they will lose, and bidder B may be able to get a windfall.

In developing second sources, the importance of timely delivery of documentation (drawings, bills of materials, etc.) is obvious; the availability of a relatively complete and accurate description of the product reduces the uncertainty for the other bidders, and the government is more likely to receive bids reflecting real differences in cost among the bidders (see Figure 4, right hand side). Where the differences among the bidders are due to one bidder having more background and experience, the government may decrease the uncertainty for other bidders by providing access to documents, reports, and other references, and provide early briefings [23].

Uncertainty Between Government and Bidders

In some if not all cases it is to the interest

of the government to reduce its uncertainty concerning the capabilities of bidders in order to be able to select the "best" bidder. And, at least in the case of those bidders who believe they are the "best," it is in the interest of the bidder to reduce the government's uncertainty. While there are other sources of information which may be used by the government, one of the main forms is the information provided by the bidders in their proposals. It is with respect to this process that the uncertainty discussed here appears.

If the bidders have a high degree of uncertainty about the information the government needs, they may have to guess as to what to provide, with the result that they may either provide the wrong information or have to over respond to "cover all bases." This is illustrated in Figure 5 by bidders A and C. Similarly, a bidder with a low degree of uncertainty, but who is wrong, may provide the wrong information (bidder B, Figure 5). As a result, the government may have insufficient information (and a continuing high uncertainty) with respect to the bidders' capabilities, or may have so much information that it is difficult to sort it out.

As was true in the previous example, the government may reduce the uncertainty among the bidders by providing information (based upon its own certainty as to what it wants) to the bidders during the bidding process [17]. This may take many forms including a full disclosure of all of the characteristics (factors) to be evaluated, what kinds of information will be helpful, how the evaluation will be conducted and by whom, and how to organize and effectively present information in the proposals.

Making Many Small Estimates

In the previous example, it was suggested that the government provide information to the bidders based upon its own certainty as to what it wants. In some cases, the complexity or uncertainty of the program may make it difficult or impossible for the government to achieve a high degree of certainty as to the information it wants [32]. No single factor, such as price in a production procurement or a brilliant technical solution in a research contract, appears to adequately describe the desired capability [2]. If the program description and the set of requirements are extensive, the bidders may respond in a variety of forms; and the combination of variety and volume may make the evaluation process unmanageable and the results uncertain (Figure 6, left hand side).

As was suggested in two of the previous examples, one way to deal with uncertainty is to divide up the estimate. In this case, dividing by time or by differences in uncertainty may not be possible; if not, divide up the estimate into a set of smaller, specific estimates, i.e., factor the problem. For each estimate, describe the specific information desired, and treat as in the previous example [13] [33]. By dealing with smaller problems, it is likely that each estimate will be less uncertain, differential weighting can be used to reflect different contributions of the estimates, extreme estimates with respect to different bidders can be identified, and differences among bidders may become more certain (Figure 6, right hand side).

SUMMARY

Uncertainty has been described as not only a problem in the procurement process but also, when identified and analysed, as a useful basis for developing solutions which minimize its effect. To aid in this process, and to supplement verbal and quantitative models, the use of graphical models is described.

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Figure 1

High Uncertainty Shared By
Government and Bidders

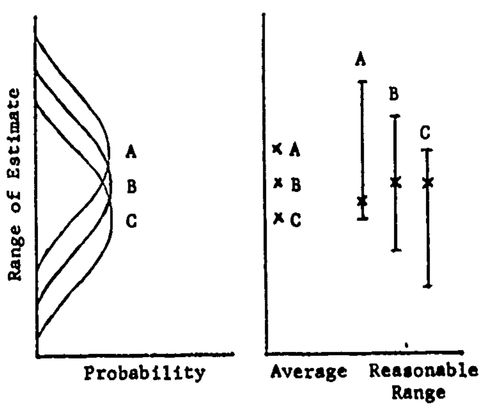


Figure 2

Uncertainty Over Time

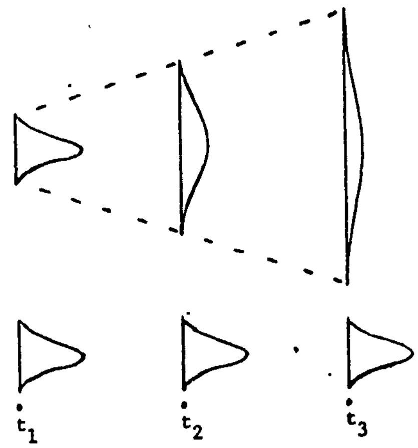


Figure 3

Separating High and Low
Uncertainty Elements

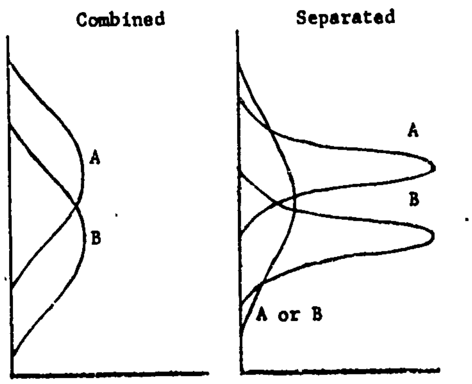


Figure 4

Differences in Uncertainty
Among Bidders

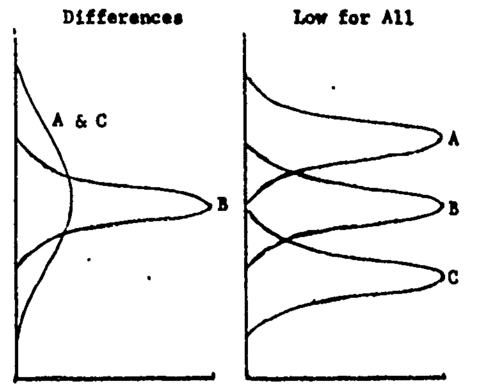


Figure 5

Reducing Uncertainty Between
Government and Bidders

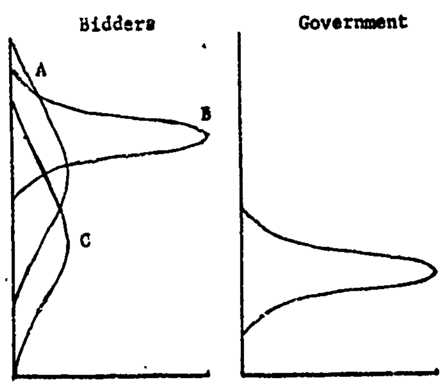
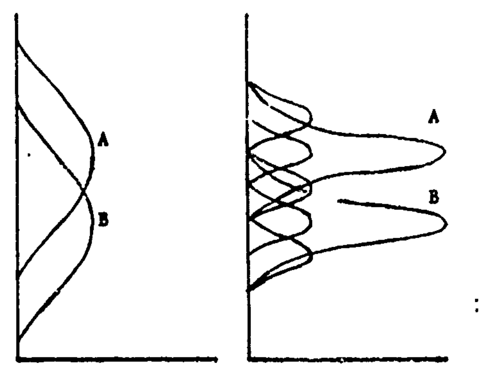


Figure 6

Dividing Estimate Into
Many Small Estimates



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ABSTRACT

TECHNOLOGICAL CHANGE AND PROCUREMENT STRATEGY

Professor Arlyn J. Melcher, Kent State University

INTRODUCTION

An important aspect of procurement strategy is the degree that specifications should be posed in terms of what product/service is required, or the performance desired. On the one hand, precise specifications may be formulated on the nature of the product/service. In this case, the contractor is provided little or no discretion in varying from the specifications. The contract is awarded to the one who can meet the specifications at lowest costs and no innovation is permitted. The evaluation--decision process is relatively simple. On the other hand, specification may be in terms of ends and performance that are desired with the specifications of means only broadly stated or undefined. In this case, the contractor proposes a product/service that will meet the required ends closest. This strategy provides the contractor broad discretion and incentive to innovate. The evaluation process is complex and cost is only one of the considerations in awarding the contract, and difficult to fix on a firm basis. The relationships with the contractor are fundamentally affected and the nature of the supervision of the procurement is conditioned by different contractual strategies.

The optimal strategy for procurement depends upon a number of factors, but two of the more important are the degree that the item is ordered on a repetitive basis and the rate of technological change. The rate of technological change, continuity of purchase and procurement strategy can be viewed as a continuum of alternatives.

Rate of Technological Change

/Slow Moderate Rapid/

Continuity of Purchases

/Repetitive Periodic Single/

Procurement Strategy

Std. spec. of product/svc. w/no specif. of ends	Partial spec. of product/svc. w/ narrow specif. of ends	No spec. of product/svc. w/broad spec. of ends

The combination of rate of technological change and continuity of purchase determine, in part, the procurement strategy that comes closest to optimally meeting governmental needs.

Continuity of Purchases	Rate of Technological Change: Slow	Moderate	Rapid
Repetitive	Std. specif. of product/ svc. w/no spec. of ends		
Periodic			
Single			No spec. of prod./svc. w/broad specif. of ends

The continuity of purchases determines the degree that adjustments can be made over time in procurement strategy. In the case of repetitive purchases, experience can be used as an input and modifications made over time if resulting performance is inadequate. The other extreme of a single contract for a major system sharply increases the risk to the government. The contract may be for a large system such as an uranium processing plant structure, a group of bombers, submarines or other equipment that is potentially rapidly obsoleted, or fills probable needs for long periods of time. In any case, a single commitment is made that locks the buyer into a long-term situation; if mistakes are made; remedies are possible--if at all--only by enormous costs. An obsolete defense subsystem, for example, can be scrapped and replaced, but at a high cost to the government and loss of credibility of all involved.

While the rate of technological change in product/service is a major determinant of procurement strategy, it has been one of the most elusive concepts for the procurement officer to practically identify and systematically evaluate in the procurement decision. This is partly because of the difficulty of arriving at a general concept that is broadly applicable and can be operationally measured.

This paper develops a broad concept of technological change, indicates the process of measuring rate of change and develops the implications the rates of change have for procurement policy. A set of propositions are offered for research and testing. The usefulness of the concepts are illustrated by profiling the technological change in the computer industry, and developing the implications that the continuity of purchase of computers and the rate of technological change have for

procurement strategy on computers.

SIGNIFICANCE

Any buyer such as the government must try to balance off two goals in its acquisition of major systems. On the one hand, one central concern is to buy the best technology at a point in time. A second concern is to minimize cost overruns on major systems. The Air Force, for instance, operates under a general policy directive (OMB Circular No. A-109) that establishes a complex decision-review process for reducing risks of buying obsolete technology and incurring cost overruns. It requires a continuing analysis of interface of mission capabilities, technological opportunities, priorities, and resources. The effect of this process is to support exploration of alternatives on the best technology available at a point in time within the constraints imposed and to delay commitment for production until performance characteristics are clearly demonstrated.

At the same time, the governmental agencies are responsible and encouraged to update their mission capabilities when technological opportunities occur. New technological developments that potentially increase agency capabilities are to be translated into mission need statements. This statement is <u>not</u> to be expressed in terms of particular equipment or technology, but in other terms such as performance characteristics. This needs statement is then forwarded for higher level review and potential budget support. This policy supports updating and innovation on the part of agencies.

Both processes require a judgement and prediction on the rate of technological change. Where technological change rapidly occurs, the exploration of capabilities of alternative systems is meaningful for only a short period of time; the choice among alternatives may be limited to equipment which is rapidly obsoleted. While the acquisition process supports buying the best available technology at a point in time and reduces the potential for cost overruns, it gives secondary attention to the rate of technological change and its implications.

The needs assessment process also rests upon a a judgement of rate of technological change. It requires recognition of opportunities and posing performance standards in terms of what is potentially relizable within the time-resource frame of agency. Clarification of the concept and measurement of technological change is central to improvement in acquisition process and determination of optimal acquisition strategy.

ACQUISITION STRATEGY

THE MAVERICK AGM-65A, A SUCCESSFUL TOTAL PACKAGE PROCUREMENT

J. F. Drake, Corporate Director, Advanced Program Plans, Hughes Aircraft Company

INTRODUCTION

This is a case history of a successful total package procurement program, the Air Force's Maverick AGM-65A. The program was initiated when many, if not all, total package programs were encountering major problems. As a result, the Contract Definition Phase (CDP) was extended, intensive face to face negotiations on all aspects of the contract were conducted, new contract terms and conditions were added, and every effort was made to anticipate contingencies and loop holes and to design "the perfect contract" from both the government and contractor's viewpoints. The resulting contract was tough, but well understood by both parties. The fact that it stood the test of time, was successful, and only one dispute went to the Contract Board of Appeals, is a tribute to the negotiators and the people who executed the subsequent program.

The RFP for the Contract Definition Phase (CDP) was issued in July 1966 and development of the Total Package Procurement (TPP) was initiated in July 1968. Test firings were completed on or ahead of schedule, with a success rate of 91 percent versus a requirement of 80 percent. All other major performance parameters were met or exceeded. Initial Operational Capability (IOC) took place after 4-1/2 years with a combat squadron in Southeast Asia. Production deliveries of the 17,000 missiles, launchers, and associated support equipment included in the TPP were completed 7-1/4 years after initiation of full scale development. Success rates in training and combat to date are 92.2 percent and 88 percent, respectively. The total program was completed at 5.1 percent over the target price.

Among indications of the program's success were the attainment by Hughes of all maximum positive performance incentives, the program receipt of the prestigious Daedalian Award and the attainment of a total of four stars by three former Air Force Maverick SPO Directors.

The Maverick program is of particular interest not only because of its success as a Total Package Procurement Contract (TPPC) but also because of the short time span required for its execution. This paper briefly describes the weapon system, the program milestones, the environment during the competition and its effects on the contract terms and conditions and duration of the CDP program performance, actions taken by Hughes to accommodate total package procurement, technical and business risks perceived during CDP (plus those not perceived) and contractual versus actuals for cost, schedule, and performance data. The paper concludes with lessons learned.

MAVERICK WEAPON SYSTEM PROGRAM

The Maverick is a launch and leave, hit to kill television guided missile designed and built by Hughes Aircraft Company. Its operational concepts and capabilities are illustrated in Figure 1. Figure 2 summarizes the characteristics of the AGM-65A and the principal ancillary gear developed under the program. (Its application to the F-111 was included in the CDP but was subsequently deleted early during the development phase.)

The Maverick missile configuration is shown in Figure 3. All of the guidance functions are located in the guidance section making Maverick the first U. S. modular guided missile. The forward firing shaped charge fires through a hole in the guidance system, then through the seeker. The warhead is the largest of its type in any operational missile and is extremely effective against small hard targets such as the ones illustrated in Figure 1. The first warhead firing is depicted in Figure 4 and demonstrates the lethality of Maverick against armored targets. The missile impacted the turret of the M47 tank. The forward firing shaped charge then penetrated the five-inch turret armor, the 11-1/4-inch thick gun breech, interior tank structure, and exited the bottom of the tank providing a "K" kill. All hatches were blown and the tank was completely gutted by fire.

The missile is rail launched from either single or three rail launchers. The launchers are carried on existing aircraft store stations and were integrated with the F-4 and A-7 aircraft without aircraft structural or mechanical modifications and with only minimal wiring changes.

The key milestones for the Maverick Weapon System program are shown in Figure 5. The date for the Statement of Operational Requirement (SOR) is approximate since at the date shown a range of missile sizes from the Hornet (≈100 lb) up to the Condor were being considered. The RFP was issued with a 200 pound warhead requirement and the CDP finally considered both 211 pound and 400 pound warheads prior to the selection of the current warhead size.

The CDP was stretched about a year. From start of DDT&E to IOC was little over 4-1/2 years and to completion of 17,000 missiles and

FIGURE 1

MAVERICK — OPERATIONAL CONCEPTS AND CAPABILITIES

associated equipment was 7-1/4 years. The latter included an Air Force exercised 413 day option for delay in initiation of production that was permitted by the contract. Although the delay seemed unfortunate at the time — program extensions sometimes become permanent postponements — in retrospect the delay gave us an opportunity to better consolidate the design.

The Category I (CAT I) tests depicted in Figure 5 were contractor conducted flight tests while the Category II (C II) tests were conducted by the Air Forc

EFFECTS OF THE POLITICAL ENVIRONMENT

The political environment during contract definition significantly influenced the resulting contract. The concepts of CDP and TPP were "in," but the latter was starting to have problems. The government reacted by tightening the terms and conditions and establishing new gates. Efforts to control cost were reflected in steeper share patterns, lower ceilings, and fixed price type contracts. In addition, uncertainties in the economy were becoming apparent — including inflation, negative balance of payments, and weakening of the government's will to maintain the wage guidelines. The public attitude toward the war in Vietnam added to the conflict between defense spending and social programs.

These political factors had a profound effect on the Maverick total package contract. The CDP was stretched almost a year to permit the Air Force to write "the perfect contract," or so it seemed. Hughes, of course, wanted that perfect contract too. The salutary effect was to permit extensive face to face negotiations between the competing contractors and the SPO. It was enervating, but the resulting communication led to a much better contract that was thoroughly understood by all parties. (Such was not the case on the SRAM and the C-5.) These negotiations also permitted the government to better assess the capabilities, the integrity, forthrightness, and capabilities of the competing contractors and their key personnel.

The share patterns were steepened f 80/20 used on previous TPPs to 70/30 and the ceiling was dropped to 125 percent of target cost. The original RFP options (3) for production were

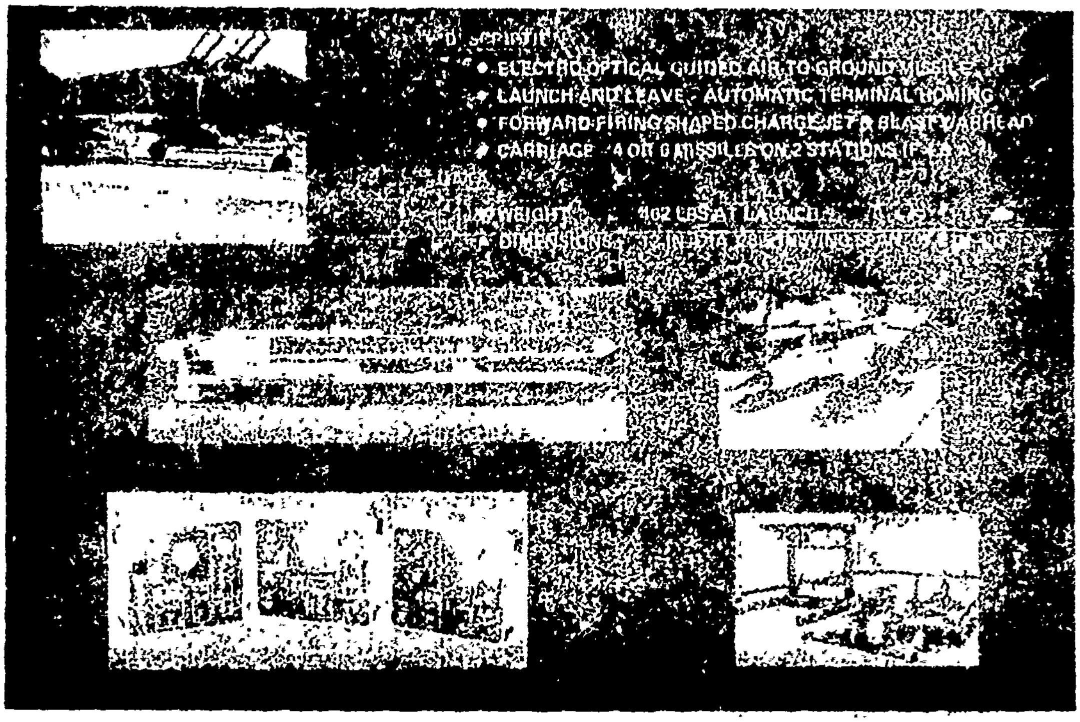

FIGURE 2

MAVERICK MISSILE SYSTEM

changed to permit the government to buy each of the second and third options in five increments. These options gave the government flexibility in adjusting to the vagaries of fiscal funding but created major pricing problems for the contractors and their subcontractors. The government ultimately exercised these incremental options on a number of the procurements.

Four "Milestone Requirements" or "Fly Before Buy" criteria were imposed, although these acquisition buzzwords hadn't yet been invented:

1) 21 successful target simulation tests prior to CAT I flight test

2) 3 spec launches at envelope extremes prior to CAT II

3) 5 successful launches prior to production go-ahead

4) CAT II conducted by AF to spec criteria.

In addition, a success record of 35 out of 40 in CAT II tests would win a \$3M incentive; whereas a 29/40 record would require a \$1M penalty; and less than 29/40 would require a redesign by Hughes and a repeat of the CAT II tests without adjustment of target cost or ceiling.

If the milestone requirements weren't passed on schedule, then the contractor had to proceed until they were passed. In the meantime, the government's obligation on subsequent milestones or procurement schedules were slipped accordingly. Needless to say, this innovation attracted our attention, as did the CAT II incentives. Prior history gave no hope of winning the positive incentives, but plenty of reason to expect either a significant negative incentive or be forced to redesign and start CAT II over. The result was that we devoted a lot of time negotiating Section 4 of the spec relative to CAT II test conditions. Hughes also negotiated a clause in the contract for a "Unique Reliability Test Program" (URT). This was analogous to the TAAF (Test, Analyze, and Fix) concepts later conceived by NAVAIR and now being included in Navy programs.

One of the major advantages of TPP from the contractor's viewpoint is that once having defined the contract in CD, there is freedom

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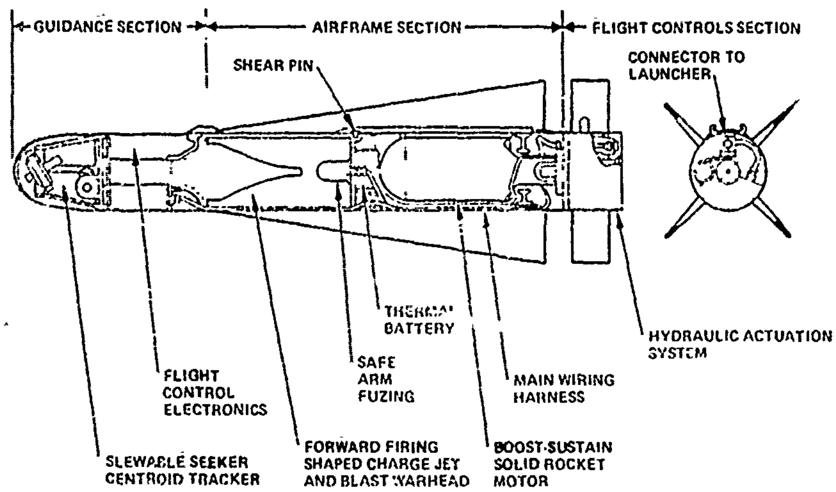

FIGURE 3

MAVERICK MISSILE CONFIGURATION

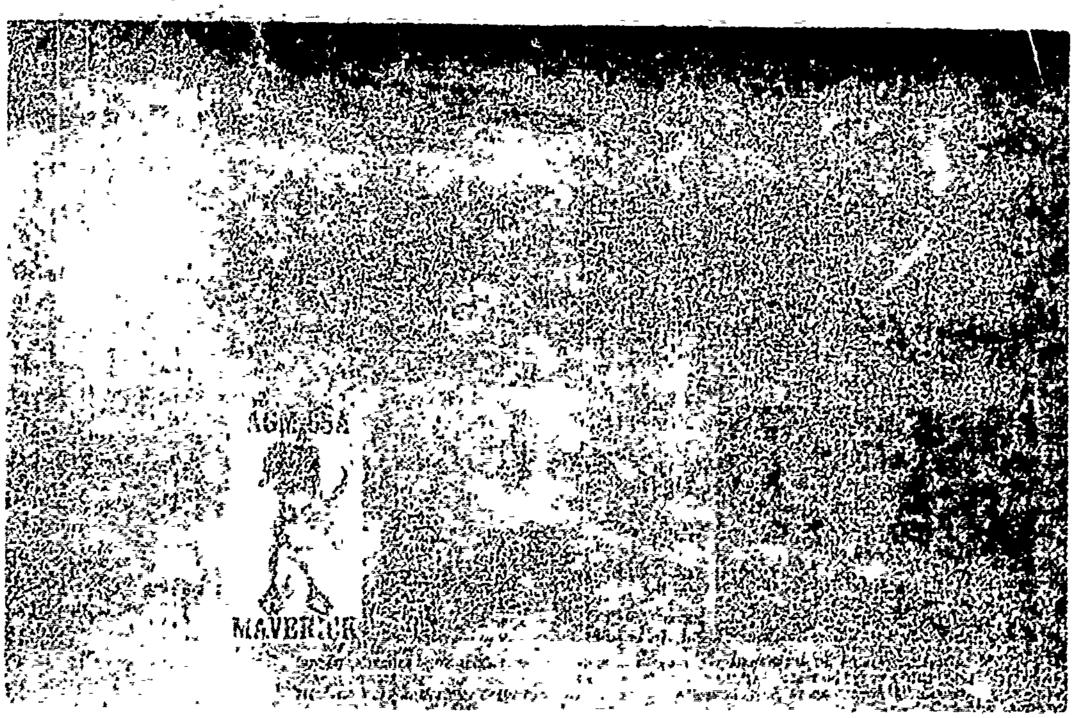

FIGURE 4

INITIAL AGM-65A WARHEAD FIRING

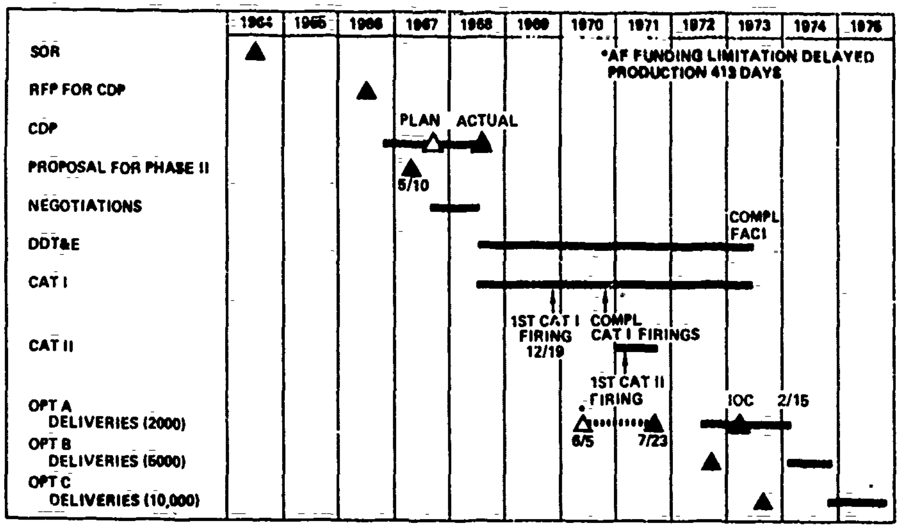

FIGURE 5

PROGRAM MILESTONES AND DELIVERIES

to proceed with the development with minimum outside review. Thus, Hughes controlled CAT I, with the Air Force monitoring for compliance with the Milestone Requirements in addition to PDR, CDR, PCA and FACI. This is a big plus when your key managers can work towards meeting the contract requirements in lieu of spending a significant amount of their time preparing for monthly, bi-monthly, or quarterly reviews.

A good Value Engineering (VE) clause should be included in any contract. The Maverick clause was unique at the time in that there were no instant savings to the contractor. No change in target or ceiling price due to approval of a Value Engineering Change Proposal (VECP) was made. Cost sharing was in accordance with the contract cost share pattern and was based on total contract performance.

Another unique clause provided for an <u>operational firing incentive</u>. Success or failure was determined by counting the hits versus the misses. The Air Force was judge and jury.

MANAGING A TOTAL PACKAGE PROCUREMENT CONTRACT (TPPC)

Key managers of the colocated vertical organization participated in the CDP and development with gradual phase-out after the initial production deliveries. Cost management was based on holding the program schedule and performance with a plan created by Cost Schedule Planning and Control (CSPC). Expenditures were about $3-4M/month; and since the program was completed on schedule, it was also on budget.

There was a lot of reporting. The best communications were daily telephone calls and a weekly report on status. In addition, the AFPRO was invited to attend the weekly Hughes staff meetings. Those meetings were always candid, so there were some indelicate Hughes comments on occasion. The AFPRO wrote weekly progress reports to the SPO based largely on these meetings, but did not repeat any of the off-the-record comments.

Our design philosophy encompassed the following:

- design for production by all parties from the start of CDP through development
- cost bogies and a responsible engineer for each major subsystem were established during CDP and were monitored during DDT&E
- well known technology was utilized unless a more inventive need was found to be mandatory
- risk areas determined early in CDP were subjected to critical investigation and test with Hughes money prior to DDT&E.

The Unique Reliability Test Program (URT) program mentioned previously was important in avoiding the dip in reliability between CAT I,

CAT II and production. The CAT I flight test program was laid out to provide early determination of problem areas (i.e., worst case test early in test program) in order to permit early corrective action without stretching CAT I. Political consideration associated with failures in flight test normally mitigate against this approach.

Financial risk was spread by careful selection of proven subcontractors for major subsystems. Each major subcontractor was offered our economic escalation clause.

RISKS

All things considered, there was a good assessment of the technical risks during the CDP. As a result, Hughes initiated tests and/or established contractual provisions such as the URT, V.E. clauses, etc.

During CDP, Hughes initiated contracts with three aircraft companies (McDonnell, LTV, and General Dynamics) for wind tunnel tests of the multiple rail launcher; and negotiated interface specs and interface working agreements to solve what otherwise would have been a formidable problem in timing, schedule and, hence, cost.

The warhead penetration problem, due to the close proximity of the guidance unit while the warhead shaped charge was forming, was formidable. Strangely, the initial warhead concept performed properly in CDP, then gave sporadic results in DDT&E. This problem was compounded at our initial subcontractor by a 10/1 reduction in his sales due to the phase down of the Vietnam war. We finally terminated the contract and went to another subcontractor.

The tracker, with a requirement for handling any tactical target under varying contrast, attack angle, lighting conditions, size, etc., was a difficult development but more manageable than anticipated in DDT&E. Tests conducted during CDP helped shape the spec for CAT II.

The fallout of unknown risks was not too bad considering the magnitude of the program. The Safe Arm and Fuze (SAF) problem could have been found during the CDP by better engineering analysis. The vidicon problems were state-of-the-art and process control. Vidicon temperature range, for example, hadn't been explored before. Making batteries is an art in design — that also is easily lost in the manufacturing process. A rocket low temperature problem was caused by over-specification by the government. It was startling to find this problem, since we had produced 40,000 Falcon missiles using the same propellant. Seals for high pressure hydraulic systems at low temperatures were state-of-the-art. Better engineering in CDP should have recognized the latter problem.

Technical or value engineering solutions were found for all of the above without significant compromise to the operational requirements.

The major business risk perceived in the CDP was bankruptcy due to lack of a proven production design. We tried to minimize this threat by spreading the risk by extensive use of major subcontractors. Business risk encountered during the contract with suppliers was far greater than we anticipated. The War versus Non-War business environment was not anticipated. The change in sales, hence operating base, was a critical and sometimes a fatal problem to our suppliers. The number of Chapter 11 losses was stunning. Part of the problem is the small business syndrome. Because of this risk, on two occasions large multi-division companies were selected. The results were not that different in the end game. A good solution to this issue is not apparent.

SCHEDULE AND COST PERFORMANCE

Thus far, reasonable coverage has been given to the background environment, effects on the contract, and the way Hughes approached the problems and risks. Much of the dialogue sounds like a prelude to disaster.

To the contrary, as shown in Figure 6, the schedule was largely met or beaten (✓). Behind schedule performance (x) occurred rarely. The overall schedule was met to within 1.1 percent. This performance was achieved by hard work, dedicated people, good management, and minimal external distraction. As an example of the latter, we didn't have to propose and negotiate a new contract every year (i.e., stabilized environment). Acceptance of good value engineering proposals by the Air Force also contributed significantly to the programs schedule performance.

The most difficult program milestone was in holding the schedule for the first flight. Overtime was extensively used in the solution of numerous and difficult problems. Subsequently, a more reasonable pace was possible.

Another difficult pivotable event was the transition from a low-delivery rate

	MONTHS FROM GO AHEAD	
	ORIGINAL PLAN	ACTUAL
FIRST JETTISON TEST	14	13 ✓
FIRST SEPARATION FIRING	14	14 ✓
FIRST GUIDED MISSILE LAUNCH	17	17 ✓
COMPL OF 5 SUCCESSFUL GUIDED MSL FOR PROD	23	21 ✓
COMPL OF 3 CAT II SPEC READINESS DEMOS	29	29 ✓
COMPL OF CAT I FIRINGS	29	29 ✓
INITIAL CAT II HARDWARE DELIVERIES	30	31 X
COMPL OF CAT II FIRINGS*	40	38 ✓
INITIAL PRODUCTION HARDWARE DELIVERY (TGM, LAUNCHER AND AGE)	45	45 ✓
FACI	54	60 X
COMPL OPT A DELIVERIES**	64	68 X
COMPL OPT B DELIVERIES**	77	77 ✓
COMPL OPT C DELIVERIES**	89	89 ✓

*CURTAILED DUE TO 26/27 SUCCESS RATE
**AF EXERCISED 413 DAY DELAY IN PRODUCTION OPTIONS

FIGURE 6

SCHEDULE PERFORMANCE

developmental facility to the high-rate production facility in the middle of the CAT I flight test program. The change, plus increasing the rate from one or two a month to eight a month while maintaining reliability was a tough job but was essential to the future success of the CAT II flight test program.

The success rate in CAT I permitted us to reduce the firing program by about 20 percent and in CAT II the nearly perfect firing record of 27/28 led to its termination with a 30 percent savings in hardware for other uses.

The CAT I and II flight test programs and ground tests of the warhead showed that the Maverick AGM-65A equalled or exceeded all the major requirements. The mission success rate was 13/16 in CAT I, 27/28 in CAT II for an overall rate of 91 percent versus the 80 percent required. The mean radial error from target geometric centroid was 3.4 feet versus 6.5 feet. (A miss is a failure; only hits are successes.)

Carrying three missiles per assigned airframe hardpoint was achieved on both the A-7 and F-4 aircraft. Warhead penetration was substantially better than the requirements.

The Maverick Launch Summary given in Figure 7 shows that the success rate has held up well after CAT I and II, including an impressive 88 percent in combat and 92 percent in training and demonstration firings.

The cost performance for Maverick Figure 8 was just as impressive as the schedule and technical performance. The total program was within 5.1 percent over target cost. Program continuity

	FIRED	HIT	PERCENTAGE
DEVELOPMENT (INCL OT&E)	123	108	[illegible]
AIRCRAFT INTEGRATION	30	27	[illegible]
COMBAT	113	[illegible]	88
OPERATIONAL TRAINING AND DEMOS	[illegible]	[illegible]	92
TOTAL	[illegible]	492	[illegible]

FIGURE 7

MAVERICK LAUNCH SUMMARY

was a major factor contributing to this success. The original target cost increased from \$323.2M to \$418.6M, of which \$78.7M was due to economic escalation and \$16.7M for scope changes. No economic escalation was provided during the first two years of the contract and a 1 percent dead band was provided around the normal projected escalation with no adjustment.

Maximum performance incentives of \$3M and \$5M were received for the CAT II and operational incentives, respectively.

The Maverick program could not have been accomplished without successful application of the Value Engineering clause. Of 143 VE change proposals submitted, 90 were approved, See Figure 9. No significant compromises in

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	ORIG CONTRACT (TGT)	ABNORMAL ECON ADJUST	SCOPE CHANGES	ADJUSTED TARGET	FINAL EXPENDITURE	% OVER TARGET
DDT&E	$94.5	$ 8.5	$5.3	$108.3	$116.0	7.1
PROD OPT A	66.7	14.3	7.4	88.4	95.3	7.8
OPT B	67.4	19.3	0.1	86.6	90.8	4.8
OPT C	94.6	36.6	4.1	135.3	137.7	1.8
TOTAL	323.2	78.7	16.7[1]	418.6	439.8[2]	5.1

1. INCLUDES LABOR LAW ADJUSTMENTS OF $1.1M

2. EXCLUDES $11.2M IN PERFORMANCE INCENTIVES AND FMS

FIGURE 8

MAVERICK TPP COST PERFORMANCE

• VECP – SUBMITTED		143
– APPROVED		90
• ICS – DDTE		$ 3.9M
– PROD		$29.2M
• FUTURE COST SAVINGS (COST OF OWNERSHIP)		$10.7M

• HAC AND MAVERICK SPO RECEIVED 1971 ASD VECP AWARD

FIGURE 9

VALUE ENGINEERING

operational capability were made. In fact, the performance is substantially better than required in many critical areas. Value Engineering savings in development and production total $29.2M, with an additional savings of $10.7M anticipated in the cost of ownership. An interesting aspect of the latter is that storage experience success rate shows that the missile can be stored for two years with successful checkouts running 97.3 percent.

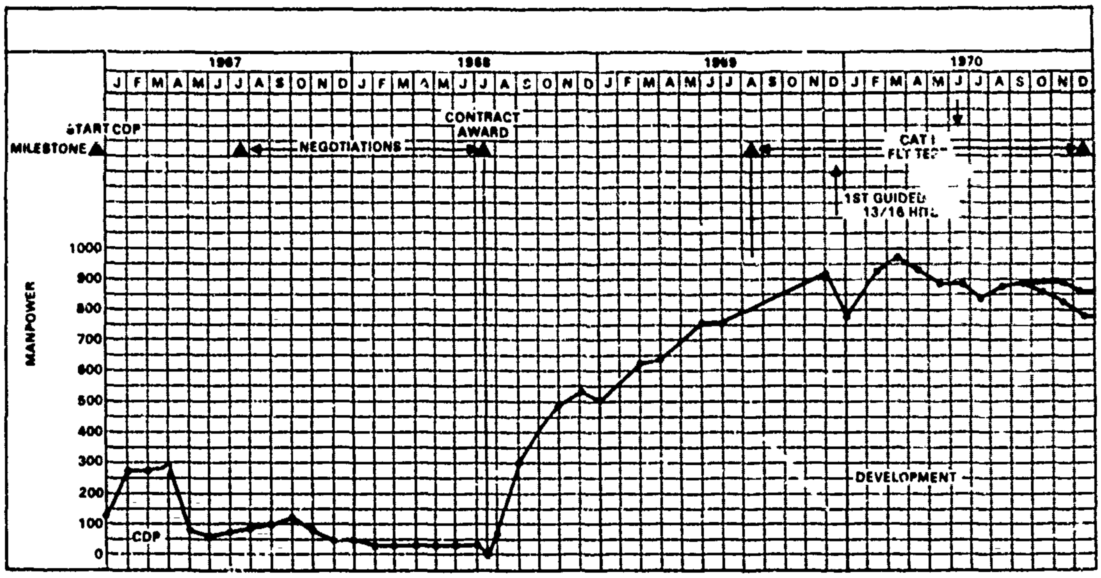
Hughes and the Maverick SPO received the 1971 Aeronautical Systems Division (ASD) Value Engineering (VE) award. Rigid adherence to the specifications and contract and rejection of value engineering changes were major contributors to the C-5 overrun (See the report to Secretary of the Air Force Seamans on the C-5 overrun).

MANPOWER

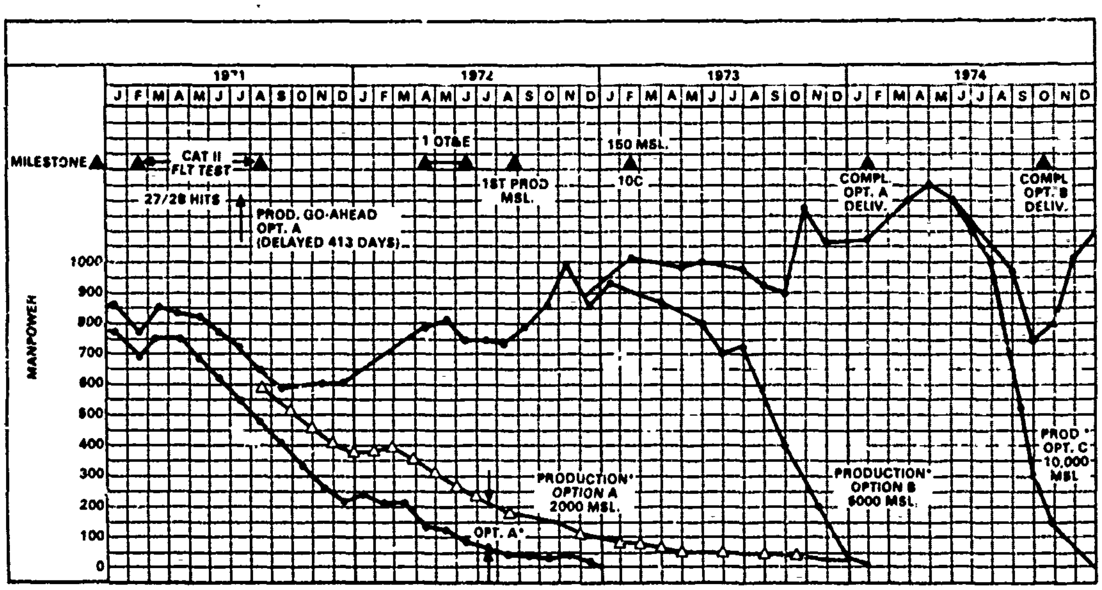
Figure 10 shows the total program manpower versus time for the Maverick program from initiation of the CDP through the initial phases of the third option. Several significant points should be made:

- manpower during CDP peaked at about 300, then dropped to about 40 during negotiation
- subsequent to start of DDT&E, there were no interruptions for decisions — program manpower was maintained as required to get the job done
- the manpower in production did not radically increase going from the 1st to 2nd to 3rd options even as the peak missile production rates in the options went from about 275 to 550 to 850/per month
- also, observe the substantial reduction in the percent of support for management and engineering from 17.4 to 7.6 in going from the 1st to 3rd option
- Long Lead Time money for the 2nd and 3rd options was included in option 1, and additional LLT money for option 3 was included in option 2.

Program and fiscal continuity permitted the above to happen with the happy results previously described. It is interesting to note that if the Air Force had not had Hughes tied to a TPPC, the AF would have stabilized at the 1st option production rate with a cost increase of 25-30 percent without consideration of inflation. Program continuity and a nearly optimum production rate paid off.



*ENGR. & MGT. SUPPORT OPTION	% PRICE
A	17.4
B	11.8
C	7.8



*ENGR. & MGT. SUPPORT OPTION	% PRICE
A	17.4
B	11.8
C	7.8

FIGURE 10

MAVERICK TOTAL PACKAGE PROCUREMENT PROGRAM

Considerable stress and effort were necessary to meet the initial flight date. The reason for the difficulty was inadequate funding to continue CDP initiated production design and program planning during the negotiation phase. As a result, our design team dispersed and was either lost to other programs or had to start with inadequate program planning or technical definition. A few $M added to the CDP for continued design and planning, small relative to total program dollars, would have avoided the problem of meeting that important first flight test milestone.

CONCLUSIONS

A number of lessons can be learned from the success of the Maverick program which are equally applicable to industry and the government.

- Program continuity provides major payoffs.
- Sequential decision making without funding and manpower continuity is an assured way of increasing cost and guaranteeing overruns.
- A fully integrated service SPO including management, engineering, contracts, finance, operations, and support, etc. permits decisive, timely programmatic decisions.
- Modest expenditures at the beginning of a program to define and investigate potential problems will prevent later schedule slippage and major expenditures.
- Careful selection of known technology appropriate to the real need and application in lieu of high risk technology is a major key to predictable performance, schedule, and cost.
- A production design, backed by system analysis, simulation and critical subsystem testing, in conjunction with a reasonably detailed CSPC program plan and extensive face to face negotiations provides the basis for good source selection without the cost in time and money for full-scale system fly offs.
- A method, such as the Maverick VE program, for the expeditious treatment by the government and the contractor of unnecessary and costly contractual and technical requirements is essential.
- The selection of optimum production rates yields large unit cost savings.
- Finally, sound engineering, good people, and strong management with a contract thoroughly defining responsibility and authority plus a little luck can achieve extremely impressive results.

KEY ISSUES IN PROCUREMENT STRATEGY IN ADVANCED TECHNOLOGY ORGANIZATIONS

Dr. Ronald L. Schill, Brigham Young University

INTRODUCTION

In recent years, shortages, inflation, and rapid advances in technologies causing product obsolescence and tremendous cost decreases -- such as in integrated circuits -- have had pronounced effects on organizational buying strategy. This paper examines several key issues which will shape organizational buying in advanced technology organizations over the next decade.

The Environment of Strategic Issues

Companies with advanced technologies* both in products and in production (assembly/process) methods tend to have problems which are accentuated by, if not characteristic of, the advanced technology environment. These problems impact ypon the entire spectrum of management, including production, finance, marketing, engineering AND industrial procurement. This paper deals with organizational buying problems, in both private and public organizations, and considers the issues relating indirectly to the procurement function through other functions in the organization.

Organizational buying processes, especially, the strategic issues involved, have been seen as of limited strategic importance until recently in most companies. A number of observers of strategic planning, including Ansoff (1), have categorized organizational buying issues as "administrative/operationsl" rather than strategic. Consequently, one of the important strategic issues is the organizational context and role which the procurement function has within the structure and operation of advanced technology companies.

External to the firm, key issues include the identification of and access to technology and the organizational dependency upon technology within the supply channel. Management of this dependency includes influencing the mixes of research, development, and production of products and production processes of key suppliers. One way to do this is to contract for these services and activities, which is costly to the buyer. An alternative way is to influence them indirectly. Of particular focus is technology utilization and development.

Identification and management of supply relationships is of key importance in advanced technology industries, since there is usually a considerable amount of exchange of technical information, financing of tooling, and access to and use of information and production data. Problems involve management of investments, financing and various risk sharing arrangements. In such a relationship, procurment personnal should play a key role in making interactions with internal efforts within supply companies. However, this philosophy is not shared by all. Recently a top procurement executive with an aerospace firm indicated to the author that relationships with suppliers should be kept at "arms length" to avoid any implications which might result if suggested actions were taken and results were poor. He indicated that companies which take a principally influential stance in management decisions and processes in supply organizations run tremendous risks of involvement beyond what was bargained for.

*State-of-the-art.

Organizational Context of Procurement

One of the key aspects of change is that of the organizational context of the procurement function --both in the system of functions and the system of structure. The system of functions --procurement process --deals with how strategic issues become included and managed, whereas the system of structure relates to the organizational level and working relationship-- boards and committees--which procurement occupies. Farmer noted that both functionally and structurally procurement has been in an administrative mode --and still is for the most part -- in most companies(2). Ammer (3) indicated the role of procurement relative to overall risk taking decisions in management:

> To general management, risk in purchasing should be avoided, because failure will cause more important activities to incur losses. The reward from taking risk in procurement may be overlooked. Thus, managements are willing to risk a loss of $10 in marketing providing the odds favor their making $100, but may reject essentially the same risk-reward relationship when a purchasing decision is involved.

This has a major impact both upon the organization and upon those who are buying from the organization. In the latter case, suppliers who treat their own procurement function in such a mode may be missing key issues and opportunities relating to the procurement function. Consequently, it may be a key role of personnel in purchasing not only to influence their own position in their organizations, but also those of the purchasing function in their supplier organizations.

The author completed research not long ago with the Raytheon company wherein the purchasing function was not managed in a strategic mode in the Microwave and Power Tube Operation. Since Raytheon was selling sole source to its captive --Amana Refrigeration --strategic issues

within the marketplace were not examined or made part of strategic purchasing planning. Tremendous increases in the market for microwave ovens coupled with drastic price decreases in components from Far Eastern imports left MPTO in a position where it could not even approach an ability to compete with foreign sources of microwave tubes in cost and quality as well asproduction quantity. This lead to a decision made in 1977 to cease supplying Amana and a fold-down of MPTO operations (4).

Typically, source relationships in industry as well as within the internal environment of the firm focus on short-term supply assurance, prices, delivery, scheduling, and other operational areas with a limited "big picture" focus. When strategic issues become recognized, they are either dealt with by other functions in the company or are left to chance solution --hoping they will go away.

The procurement function is both shaped and provides shaping to the state-of-the-art environment. Within a climate of technological change, where results are uncertain, there are considerable risks in decisions. One key response which has occurred at Raytheon is the horizontal, rather than vertical, organization of the function. That is, buyers tend to specialize in specific commodities/components and learn the markets for these items. This type of organization has lead to Raytheon's Materials Strategy Council (5). The company uses several company-wide contracts for common materials with buyers specializing in semiconductors, for example, buying for the whole company. The Council is a group of buyers in a common commodith not bought under a common contract, but who meet monthly (representing their own planst and divisions) to share information and strategy.

Another key issue influencing procurement was identified long ago by former AFSC (U.S. Air Force) Commander, Bernard Schriever (6):

> The pacing factor in acquiring technologically-based modern aerospace systems is management, not science and technology.

The ability to develop and implement effective management systems for systems acquisition is a top priority in the aerospace industry. Other more recent acqknowledgements of this are represented organizationally in the formulation of the Office of Federal Procurement Policy in the Office of Management and Budget, and the Federal Procurement Institute, both of which are charged wich major organizational roles. Within the Air Force organizational changes have occurred within AFSC in expanding the procurement office to include "manufacturing" as well as procurement. This office has key interest in management of manufacturing technologies within the industry-base. Finally, the Air Force Business Research Management Center has been charged with responsibility for researching procurement problems and management in order to improve the process of aerospace buying.

Key studies within the U.S. Government include the OFPP pamphlets and directives which have been published in recent years (7), the Bell Report (8), the AFSC conference proceedings (9), the Standord Research Institute report (10), and the more recent "Profits 76" study (11).

Technological Access and Transfer

In addition to organizational changes, issues dealing with technology access and transfer are also emerging with increasing stratetic significance. The process of technology acquisition, not merely materials and hardware buying, is an emerging part of strategic procurement. Three important issues relating to the technology base to which a company has access are (1) gaining access to new and rapidly changing technologies, (2) providing incentives both internally and externally for technological development and change, and (3) sharing the risks associated with technological change. Just as production decisions involve "make or buy" so do technological decisions --do we develop the technology in-house or contract for it? This question is becoming more and more a part of strategic procurement management.

A major issues is recognizing the extent of dependency which an organization has upon its suppliers with respect technological access. For example a procurement manager might be quite constrained in negotiation with a company upon whom his organization is dependent for major technology change and severely limited in alternative options.

Incentives for technological change include both organizational, financial, and marketing issues. Often incentives are based upon projected market potentials for new products and upon the development of good marketing strategics for exploiting new technologies in order to make justifiable the large capital outlays whicm may be involved. Market forecasts can be "shakey" because of the potential obsolescence which the high technology environment provides for itself. Consequently, the very market opportunity which makes possible a new product can also spell its future in quite negative terms.

Technological access and transfer involves both products and production technologies. Getting suppliers to make needed capital commitments to modernize production facilities can be a major procurement problem. The author recently researched Sears in the area of new product development wherein the company had some major difficulties in getting sources to invest in new product design changes because of the fear that product life cycles would obsolete the new products before tooling could be amortized. Innovation in the marketplace can spell difficulties for procurement managers aimed at gaining innovation among suppliers.

Typical among the various problems of tech-

nology transfer, in addition to technology incentive, are various methods in supply agreements, such as (1) coproduction agreements, (2) teaming arrangements, (3) licensing arrangements, (4) buying out entire plants and companies, (5) contracting for training in high-technology areas, and (6) financial support of various kinds. One key problem is that when technology is shared, it can be modified by the recipient and it gradually loses its identity and proprietary nature. Frisbee (14) noted that U.S. control was minimal over the export of indigenous technology through its allies wxcept through voluntary cooperation, and that the Soviets have bought from the West nearly 1000 complete manufacturing plants ranging from automotive products to chemical, electronics and metallurgical production. The Department of Defense is in the process of refining, simplifying, and expanding its machinery and procedures for analyzing incipient dangers in the export of specific items of U.S. technology.

Management of R&D and Product Mixes

To the extent that a company is integrated backward it becomes less dependent upon external production and technology in competing for key resources. However, too much internal control can limit acquisition and access to the variery of competing sources. The content and pace of the research-mix and the development-mix of suppliers and potential suppliers is a key issue in strategic procurement planning. Traditionally procurement managers have taken a passive role in this regard settling for whatever suppliers come up with --with the exception of R&D contracts. Purchasing personnel play a very little role in influencing supplier marketing decisions. This stems largely from -he lacking entrepreneurial role which most procurement managers see for themselves and in assumed prerogatives that marketing takes the initiative in product development. However, procurement personnel can occupy a strategic "boundary spanning" role in managing the outside forces affecting the supply marketplace (14).

Strategic management of product mixes includes providing incentives and negltiating even the diversification of potential suppliers into a line of effort and new technologies and products within the "demand perspective" of the buying organization. This can influence the technical directions as well as the "down the road" acquisition of output and can result in major product mix changes available to the buyer. The opportunity for influence is broad, ranging from the acquisition of technology to how the supplier deploys and uses that technology within his own organization as well as with respect to the selection of <u>his</u> supplier and customer bases.

An important issue is the management of expectations. This includes the development of a "market" for technology within the buying organization without commitment to single source or "must buy" implications. However there must be an expectation that if the results of the supplier are sufficient and his offering is competitive, there exists sufficient cash flow to justify his capital outlays. Consequently, procurement managers must be good marketers, perhaps knowing good marketing strategy for their suppliers --even suggesting it to them. Consequently, a key issue in the role of a strategic procurement manager is management of the supply and demand within the supplier/marketer channel.

Such an entrepreneurial role can have anti-trust implications. Purchasers must be aware of just how far they can go without causing a significant restraint of trade and collusion. So far laws have been interpreted quite freely in many instances, especially where Government interests favor teaming arrangements between prime and subcontractors.

Figure 1 shows a typical model of supply and marketing operations within a channel:

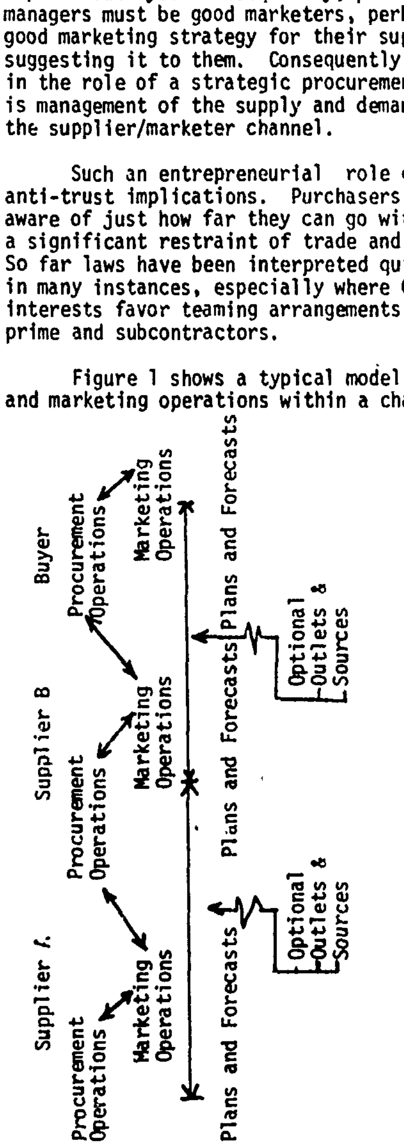


Figure 1: Supply/Marketing Channel Coordination Requirements for Technology Development and Marketing

This shows a three-tiered supply and marketing system. Supplier A makes some acquisitions, such as raw materials, and these must be coordinated internally within A and with the purchasing plans of B. The first case demands an intracompany planning and forecasting system, while the latter is channel oriented planning and forecasting. The same is true for B with respect to buyer C. Each organization has options outside of the system for marketing and for purchasing, an assumption that is not always true.

Where supplies of materials or technologies exceed within system demand, outside marketing may occur. Conversely where demand exceeds supply, outside buying can occur. When technologies are involved, instead of products, this outside sharing can be detrimental to the system and reduce system-wide effectiveness as a competitive unit.

Technological decisions in supplier organizations include decisions relating to technology applied to such areas as design to cost, long-range forecasting of supply needs and the role of technology in product mixes. When efforts are geared toward matching technical feasibility with market opportunity, a viable competitive system unit is born.

Quinn and Cavanaugh (15) raised the issue of procurement playing a role in influencing whether and how much research suppliers should do, what portion goes to basic versus applied research, what technology content and objectives are sought, and the level of expenditures allocated. In most situations if this is done at all it is done very indirectly and merely by encouragement. Each of these areas can have a major impact upon "down-stream" costs and the competitive profile which the supplier will have. Relevant costs can include process costs, investment costs, costs associated with product performance, down-time, and life cycle costs. Gaining "up-front" effort can become a key opportunity for the buying organization if the procurement manager plays such an entrepreneurially strategic role.

Inherent in this role is the buyer's responsibility to forecast changes, directly and indirectly, in technologies and the forces shaping technologies (such as cost reduction in the semiconductor industry). Procurement managers can play a key information system role within and between organizations if they are focusing upon such issues. Such forecasting becomes an important decision-making tool where up-front investments are made and down-side risks must be analyzed. Strategic supply impact studies, identification of emerging technologies, resource management plans, and strategic resource needs studies can all play an important role in this type of analysis. More myoptic buyers get engrossed in price haggling and expediting that causes them to miss strategic issues.

Strategic Planning Issues

The environment of internal and external technological change provides considerable opportunity for conflict to occur among the supply and marketing channel members. Part of the role of procurement is to identify and manage this conflict. Organizations in the channel relate over a wide range of issues and activities, and prerogatives can be held where functional responsibilities can become sources of irritation in such areas as financing innovation, compatibility of capabilities, and cost/price analyses. A supplier which is seen as dynamic and progressive one day can be considered too much that way later on when he wishes customers to expand the breadth and depth of their buying. On the other hand, a supplier that has spent considerable sums in tooling can balk at efforts to produce new products when his present tools are not yet amortized. Consequently, supplier selection and evaluation criteria need to take innovativeness into consideration as well as the extent and rapidity with which it changes over time. When considerable coolaborative dealing is needed, as is often the case in high technology industries, this can cause conflict which is counterproductive to the technological environment itself.

It becomes important that procurement managers profile the strategies of their own companies, of their current and potential suppliers, and competitors in order to have the needed information to make good strategic decisions. Such profiling is usually limited to short-term issues such as price, capacity, delivery time, and so forth. Audits of supply markets and individual suppliers in areas of costs and technical leadership change become critically important.

Sales market forecasting has been developed as a science for a number of companies, but supply market forecasting is even lacking in conceptual models beyond mere commodity price forecasting. Supply market forecasts need to include not only materials availability, but also technological forecasts and changes in the entire marketing activities of suppliers and supply markets. Understanding market characteristics and the forces behind those characteristics is a key element of strategic procurement. Roman (16) distinguished between commercial and government markets in a number of criteria. His model is modified in Figure 2.

One key operational issue is understanding and responding to product/institutional life cycles of suppliers. Although the concept of life cycles was initially developed to include sales growth over time, there are significant changes which occur over the cycle which influence procurement plans of buying companies. Among these are:

(1) Changes in competitive strategies of suppliers, including changed positioning, market share targets, price/cost data, and quality.

(2) Changes in demand for resources as more and more marketers become involved in selling the product and more and more buyers compete for sales.

(3) Changes in product profitability over time, causing changes in organizational goals and strategies.

(4) Changes in markets and supply/sales logistics factors.

Investment/Finance/Risk Issues

Market Characteristic	Commercial Markets	Government Markets
Procurement Method:	Systems approach	Components approach
Facilities and Capital:	Marketer provided	Buyer provided (often)
Urgency:	Dependent on market need	Dependent on mission, high time emphasis.
Underwriting of risk:	Seldom by customer	Often by customer
Profit policies:	Market forces	Customer policy
Basic research:	Seldom procured by customer	Often procured by customer
Applied research:	Sometimes contracted for	Often con-racted for
Personnel shifts:	Infrequent	More frequent
Lead times:	Sometimes long/market tests	Usually long
Product life cycles:	Varies by demand	Varies by funding decisions, A managed decision.
Controls:	Less direct influence	Often direct influence
Direction and thrust:	Market directed	Technology directed
Certainty of future:	Often multi-year contracts	Decisions by governing body
Market condition:	Salability	Mission need
Cost orientation:	Within demand valuation	Budget oriented
Project selection:	Return on investment	Priorities of mission
Competitive orientation:	Direct	Indirect
Operating control:	In hands of supplier	Regulation oriented

Figure 2: Contrasting characteristics of procurement/marketing operations with respect to markets between commercial and government buying organizations.

There are different types of risks as well as different amounts of these types of risks associated with procurement of advanced technology items. Types of risk include:

(1) Technical risk -- Can the project be done?

(2) Time risk -- Can it be done by need date?

(3) Cost risk -- Can it be done in the budget?

(4) Obsolescence risk -- when delivered will it be too old?

(5) Capital recovery risk -- will the return on capital needed be realized?

(6) Management prerogatives risk -- is management capable of handling the project?

(7) Contingencies risk --What will happen that isn't seen today?

(8) Market development risk --Will the market still want it when it is available?

(9) Competitive advantage risk -- Will competitors who want until we commit have a lead with a better product?

Technical risk is associated with the state-of-the art and is influenced both by the distance from that state and the relative change velocity of the state. Thus risk assessment in a technical sense must address these questions. Recent research has indicated that Government contracts over the past several years have run into overruns as -uch as 1.8 times average for time and 2-3 times in cost. These are end results of risks in the above areas.

Risks are accentuated by the nature of the procurement --and, consequently, upon the buyer's ability or inability to command and manage risk variables. Inherent in the buy decision is the paying of a profit to the supplier to manage the project, and consequently, some buying philosophies take the point that since the supplier is is being paid to manage, buyers should not take an aggressive contract management role. Such a philosophy is like telling a foreman he is being paid to manage a shift and not having management checks to see that he indeed does that.

Responses to risk vary, and the following are some approaches used. Discounted cash flow analysis regarding proposed capital outlays has become increasingly more important in procurement management. Contracts --often referred to as "supply agreements or definitive agreements" can vary in the means for sharing risks. Possibilities include redetermination clauses for risk factors, data rights, unpriced options, tailored incentives, sharing of costs, and escalation clauses, to name a few.

A significant investment problem recently

addressed by the U.S. Government is that of risk of obsolescence in facilities in the industry base. The problem has been tagged "assurance of industrial preparedness," as an extension of the concept of "military preparedness." This indicates that a key element in defense strategy goes beyond the military system into the industry base. Research has indicated that there are signs of certain factors in the industrial base having neither the capacity nor the desire to respond to defense surge requirements. The reduced capability of industry to respond will have progressively serious implications for the U.S forces. Similar problems often exist for mass marketers --such as the example of Raytheon-- when demand surges occur and market shares change.

A remedy used in commercial industry is multi-year contracting to provide for capital recovery over time. However, in Government procurements, the buy is budgeted on a year to year basis. Both Boeing and McDonnell-Douglas provide classic examples of considerable investment risk taken in an environment often lacking in even letters of intent (17). Where a one-year contract occurs, or when an entire program can be "scrapped" by a Government decision --such as B-1-- time/investment risk management is difficult. Evans commented (18):

> Firms that fail to replace obsolescence and inefficient production are going to feel the results... we are on an avant-garde in technological innovation of products, yet (are) still slipping in manufacturing obsolescence.

Other solutions are debated, including termination liability for buyers, guarangeed amortization, interest credits for financing charges, increasing allowable profits, and various sharing arrangements. When heavy "front end" investments are involved, such as in the manufacture of the Boeing 747 aircraft, it is important to get such provisions as termination liability and risk-sharing by customers. Often this is needed to obtain financing for the manufacturer.

CONCLUSIONS

The procurement function will become more and more strategically important to companies over the next decade, and this is particularly true to high technology companies. In such companies the various perplexing issues discussed above will provide a major stimulus toward a strategically-based procurement function.

Within the next decade, considerable change and progress will occur in the following areas of procurement:

(1) Changes in the organizational context and role of the function.

(2) Better strategic identification and management of technology access, dependency, transfer, and incentives in supply relationships.

(3)A larger role --perhaps even an entrepreneurial one --for procurement managers with focus on influencing marketing operations of suppliers, such as research and development and product mixes.

(4) Management incentives and programs for developing technological changes in production methods and processes used by suppliers to create better cost efficiencies.

(5) Better identification and management of supply channel conflict.

(6) Improvements in procurement information systems for early detection and forecasting of changes in technology and other strategic issues.

(7) Better coordination of procurement strategy with other corporate strategies.

(8) Improved methods of investment and finance risk sharing.

The time to start preparing for this role is now, and companies and other organizations must recognize that the frontiers of industrial advance rest more and more on managing the acquisition of resources --material and technical-- or else the "future shock" that is at the doors may "huff and puff and blow the house down" for laggards who have built their procurement homes of strategically unsound materials.

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ACQUISITION PLANNING FOR THE NAVSTAR GLOBAL POSITIONING SYSTEM JOINT PROGRAM

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Planning for a weapon system acquisition is a complicated challenge. Since there are many disciplines associated with acquisition, operation, maintenance and support, current regulations strongly suggest including representatives from each of these disciplines in the planning process. The regulations do not, however, take full advantage of the experience, skill and expertise of industry, a major partner in a weapon system's life cycle. In order to draw upon this vast reservoir of experience, Air Force Systems Command uses draft RFPs and often extends proposal times to allow for contractor comment on our requirements. Unfortunately, it seems that for one reason or another, contractors contributions are frequently cosmetic. Perhaps fear of giving away their approach to the competition is a contributor. However, an equally significant factor is industry's general disbelief that Program Offices want comments. "Not invented here," though few will admit it, haunts us all.

The NAVSTAR Global Positioning System Joint Program Office (JPO) and the SAMSO Deputy for Procurement and Manufacturing recently conducted a Business Strategy Panel (BSP) in which acquisition strategies were developed for Full-Scale Engineering Development. Program Office and procurement personnel went through the normal planning, trades and analyses prior to the BSP, except for one interesting twist. They obtained business inputs from industry before finalizing their acquisition strategy.

The process went like this. First, a Government planning group developed several alternative strategies. However, instead of completing an analysis of the alternatives and recommending one to the BSP, they allowed time to query industry. Prime sources were sought and briefed on the Government's requirements and its current thoughts on acquisition strategies. Program budgets were discussed and each potential procurement was scoped for cost. Then, industry was given an opportunity to return to brief the planning group on the strategy that would increase the potential for achieving program goals within cost, on schedule, and with the least risk to both parties.

The ground rules established this to be a business discussion - not a technical briefing or marketing pitch. Industry was given the fiscal and schedule constraints of the program and was told to challenge requirements that were unachievable. They were also given a written list of questions to use as a "strawman" in developing their own strategy, if they perceived that none of the Government's alternatives were optimum. The Government then requested that corporate business management either present the briefing or participate in strategy development.

How did all this work? We think the results were phenomenal. Nine of the eleven original companies involved, briefed us. The briefings evolved into open discussions with small but equal representation on both sides. The senior members of the planning group represented the Government and many companies brought vice presidents to represent them. The Government planners did not enter the briefings with a general consensus and it was evident industry did not either. This stimulated an excellent open exchange of ideas. What did we get out of all this? Almost all companies took the opportunity to present their strategy, and although each company's strategy was understandably favorable toward its own strengths, we all benefited and achieved a great deal of insight into each other's thought processes.

As each briefing progressed, it became readily apparent that the Government knew a lot less about industrys' desires than we thought we did. (Only once did the Government team guess what a company would suggest for a business strategy). Our analysis of industrys' briefings, overlaid on our acquisition planning led us to an acquisition strategy that is not optimum - but is the best available, considering real world constraints. Industry now knows what types of contracts and incentives we are contemplating, how much money is available for the total acquisition, what we want to achieve with our funds and that we want maximum competition for a realistic, achievable program. This should encourage draft RFP comments and discourage buy-ins.

Would we recommend continuing this approach? You Bet! It makes good business sense.

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PROCUREMENT STRATEGY FOR SATELLITE AND SPACE SYSTEMS ACQUISITION

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ABSTRACT

Procurement of Satellite and Space Systems is funded in the same way as other systems are procured, by full funding. Although this method is required by Congressional, DOD and Air Force guidelines and regulations, it is not tailored to the peculiar characteristics of space systems acquisition, high technology and low volume production.

The objective of this study is to describe the environment within which space systems acquisition takes place and to emphasize how the traditional weapons systems acquisition process is applied. The study defines managerial and technical impediments which are engendered using full funding within the systems acquisition process. Innovations to the existing systems acquisition strategy are proposed and conclusion emphasize the need to convince Air Force, DOD and Congressional authorities that space systems acquisition effectiveness could be enhanced if current guidelines are modified.

DESIGN TO COST

DESIGN TO LIFE CYCLE COST IN THE AMST PROGRAM

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INTRODUCTION

You need some economic advice. Your company's old fleet of short-haul, specialized delivery trucks have given good service for over 20 years but most are now worn out. What's worse, the company has developed a whole new product line to meet some stiff competition and the new equipment simply won't fit in the old, narrow body trucks. Even with smaller items, the old trucks couldn't make deliveries directly to the construction sites where the equipment was needed. Some of your more daring drivers have tried to in the past and thus have contributed to the list of worn out and broken trucks.

So the company president has directed you, the chief of purchasing, to buy a new fleet of trucks with wider bodies and the ability to get in and out of rough construction sites with heavy loads. As a smart manager, you're trying to buy a fleet of trucks that will do the job for the least money. You've already had several meetings with both the fleet manager and the company president, and you have negotiated from them a set of minimum essential requirements for the new trucks. You have found two reputable truck manufacturers who have designed new prototype models that look very promising. With a few design changes, either truck model appears to meet your minimum essential requirements. You're ready to solicit bids, select the one which meets your requirements at the least cost, and get on with the job.

WHAT COSTS? - Are you really ready? What "costs" should you consider in the selection? The company's chief of maintenance has given plenty of advice on this question. He says that maintenance costs are growing by leaps and bounds. Labor costs, fuel costs, and the cost of parts have skyrocketed. He wants you to give strong consideration to the cost of operating and supporting the trucks over their expected lifetime. Another meeting with the company president confirms that your selection should be based on the total cost of buying the new trucks and the cost of operating and supporting them over a 20 year period.

With help from the chief of maintenance and the two manufacturers (who are suddenly very interested in operating and support costs) you begin to get your act together. You find great quantities of historical data on operating and support costs for truck fleets. You even find several groups who are actively predicting these types of costs. Several coordinated analyses later, you have a cost prediction technique that all agree will allow you to select a truck with the lowest predicted life cycle cost. You're also beginning to find ways to cut down some of your "minimum" requirements and improve the design to lower the total cost. Now you're even getting smart enough to ask the questions.

HOW CAN YOU BE SURE? - How can you be sure he will develop and build the trucks to meet a predicted total lifetime cost? As you ponder this question, the vice-president for accounting speaks up. He says it's great to select the best truck based on total cost, but after that you'd better just worry about the production cost. He wants you to give the contractor a production cost goal a few percent below his bid price and put in some incentives and controls to have him design the truck to this goal. He says you can't really predict life cycle costs, and with the limited budget next year you'd better just make sure you can buy the truck at the bid price. Just to make sure, he asked the company president to make your Christmas bonus next year contingent on meeting the production cost goal. Now you know you need some advice. But let's get back to real life. This little story is analagous to a situation now being faced in the Air Force by the Program Director of the AMST SPO (that's the Advanced Medium STOL (Short Take-Off and Landing) Transport System Program Office) at Wright-Patterson AFB, Ohio.

THE AMST PROGRAM

The AMST is a medium size jet transport aircraft with a wide body for outsize cargo. It incorporates simple but effective powered lift technology and heavy duty brakes to enable it to take-off and land with heavy loads on short runways. It's rugged landing gear and high flotation tires permit the AMST to operate repeatedly out of short, unimproved dirt strips where the action is. The high lift technology also helps the pilot to rapidly climb and descend in tight circles over the airfield to escape anti-aircraft fire from any nearby enemy gunners. The AMST's wide body is designed to carry all of the Army's new outsize firepower equipment and heavy armor, even the 58 ton Main Battle Tank. Another wide body benefit is the ability to carry both troops and supplies or equipment

in the same load, with the troops sitting in side-mounted seats alongside the cargo.

AIRLIFT MODERNIZATION - The purpose of the AMST is to modernize the Air Force's current tactical airlift capability, which is rapidly being depleted and is deficient in a number of areas. STOL aircraft such as the C-7 and C-123 are virtually gone from the active fleet; the few serviceable combat aircraft remaining have been transferred to the Air National Guard and the Reserve Force. The active force's C-130, a tactical airlift workhorse for over 20 years, is deficient in its ability to operate safely and routinely from short, austere fields. It's turbo-prop engine is efficient but gives it a relatively slow speed. With an inadequate payload and a narrow body design, the C-130 cannot carry a large percentage of the Army's modern vehicles, not even the MICV (Mechanized Infantry Combat Vehicle), the primary combat vehicle of the Army's Mechanized Infantry Battalion. The Air Force is also facing a large-scale replacement of the C-130 fleet due to service life exhaustion. The AMST provides the option to modernize this aging and depleted force with a single aircraft which can operate out of short, austere C-7 and C-123 type airfields and carry over twice the payload of the C-130.

THE AMST PROGRAM - The AMST Program is now ready to proceed from a prototype advanced development phase into engineering development and subsequent production. The prototype program was the result of a formal source selection competition open to all U.S. aircraft manufacturers. From the five companies who participated, Boeing and McDonnell-Douglas were selected to build and flight test two prototype aircraft. The Boeing YC-14 and the Douglas YC-15 have each completed successful prototype flight test programs, and the two companies are now competing for the follow-on development/production program.

Transition to Engineering Development. A transition phase between prototype and engineering development led to several program refinements. To hold down costs, Army and Air Force requirements were scrubbed down to a list of "minimum essential requirements" agreed to by the Military Airlift Command in their Required Operational Capability (ROC) document. Limited development funding called for a unique approach. The austere "Minimum Engineering Development (MED) Program" will include further development/operational flight testing using the prototype aircraft, modified to the production design, with a limited verification test on production aircraft. Concentration on low production cost, which was a major factor in sizing the aircraft, has been expanded to include emphasis on lower total life cycle costs. A number of study efforts were conducted in such areas as life cycle costs, design definition, and Integrated Logistics Support. The transition phase included the development of management plans to guide the contractor's development/production effort, and the contracting approach to blend these efforts together.

The AMST Contracting Approach. The AMST contracting approach emphasizes life cycle costs and includes three separate contracts aimed toward minimum total cost. The MED contract will provide design, development, and testing of the aircraft and related equipment. The contract requires the use of existing commercially certified engines which will be leased by the contractor for the prototype test phase. The contract includes an award fee to motivate the contractor to follow his plans and to minimize downstream costs. The MED contract calls for three priced production options for up to 60 aircraft out of a planned buy of 277. The aircraft contractor will supply the engines for the first three production options, after which the Government will provide the engines as GFAE. This portion of the contract includes a large performance fee based primarily on the results of two 30 day Operational Readiness Evaluations (OREs). During these evaluations, Air Force crews and maintenance personnel will accomplish a predetermined set of operational missions under simulated operational conditions. The OREs will measure key elements of operating and support (O&S) costs such as aircraft maintenance manpower, aircraft reliability, material usage, and fuel consumption. The first ORE will occur after delivery of the seventh production aircraft. The second will be accomplished on a complete operational squadron approximately two years after the IOC (Initial Operational Capability) date.

A separate spares contract will be negotiated in parallel with the basic MED/Production contract. The terms and conditions cover pricing procedures for the acquisition of initial and replenishment spares concurrent with and at the same cost as the production installs.

An Interim Contractor Support (ICS) contract will also be negotiated in parallel with the basic contract. The contract will provide up to three years of contractor support for spares and depot level maintenance until the USAF obtains this organic capability. Special negative pricing incentives are included to motivate the contractor to support an early organic capability.

These and other provisions in the AMST contracting approach are intended to emphasize life cycle cost and result in a weapon system with the minimum cost over its expected lifetime. Life cycle cost will be an important consideration in the selection of a winning contractor. Some major trades have already

occurred based on reduced life cycle cost. Others are expected to occur as the design is solidified during the MED and Production program.

THE DESIGN TO LIFE CYCLE COST CONCEPT

BACKGROUND - A Department of Defense Directive (DODD 5000.28) requires that major defense systems acquisition programs apply a "Design to Cost" concept using the Joint Design to Cost Guide (AFLCP/AFSCP 800-19). The intent of this direction is clearly focused on life cycle cost. The directives specify that life cycle cost goals be established "to which the system will be designed and its cost controlled," and that "practical tradeoffs between system capability, cost, and schedules must be continually examined to insure that the system developed will have the lowest life cycle cost consistent with schedule and performance requirements."

The application of this concept begins to digress from its stated purpose. While recognizing the need to control total life cycle cost, the directives specify that the initial "difficult but achievable" Design to Cost goal "shall be established in the form of Average Unit Flyaway cost." The stated reason for limiting the goal to production cost is "because of the ability to more accurately estimate production costs and the supportive production cost data base available." Changes to a Design to Cost goal must be approved by the Secretary of Defense and are generally approved "only for major changes .....where a significant demonstrable reduction in life cycle costs can be achieved, or for program changes beyond the control of the program manager." In practice, DOD has set very difficult goals, usually below the official program estimate, and changes to these goals have been hard to come by, even for the good reasons stated above. For these and other reasons, almost every major aircraft acquisition program has failed to meet its Design to Cost goal, as illustrated in Figure 1 for two of the major Design to Cost programs.

DESIGN TO LIFE CYCLE COST OBJECTIVES - The AMST program manager proposes to use a "Design to Life Cycle Cost (DTLCC)" concept in his management of the AMST Program. This concept is designed to embrace the full intent of DODD 5000.28 and to avoid the pitfalls of the current application of "Design to Cost." The objective of DTLCC is "to minimize the total cost to the Government of development, production, support, and operation of the AMST system within defined constraints of budget, performance and schedule."

FIGURE 1

WHY HAVE PROGRAMS NOT MET THEIR DTC GOAL?

Reason	PROGRAM A	PROGRAM B
Goals Unreasonably Low	X	X
Requirements Changes	X	X
LCC Trades	X	X
Schedule Changes	X	X
Unforeseen Problems	X	
Lack of Contractual Incentives		X

Source: Interviews with Program Office personnel.

The DTLCC concept includes the following subobjectives:

1. Life cycle cost shall be considered equal to performance/technical requirements and schedule throughout the design, development, and production of the AMST.

2. Development and production costs shall be balanced against the costs of deploying, supporting and operating the system. Where significant outyear savings are possible, additional investment costs will be pursued.

3. System performance requirements, design/production requirements, and concepts for operation, employment and maintenance will be continually reviewed and updated to insure that the minimum life cycle cost design is achieved for the projected airlift needs.

4. Contractual provisions shall be provided to task and motivate the contractor to implement a meaningful DTLCC program within the contractor's organization.

5. DTLCC awareness by both Government and contractor personnel shall be achieved by continual management emphasis at the corporate level, exchange of ideas on current problems, designer visits to depot and operational units, etc.

THE DTLCC GOAL - The DTLCC plan represents, in effect, a contract between the Air Force and the Department of Defense to develop the AMST aircraft to a single, total life cycle cost goal. This goal is expressed as the sum of the following four cost elements normalized

to an individual aircraft and expressed in constant Fiscal Year 1977 dollars: Minimum Engineering Development Cost, Weapon System Cost, Other Support Costs, and Operating & Support Costs.

The DTLCC plan defines each of the four cost elements to include both contract and in-house Government costs. MED cost, for example, is defined as all program costs funded by the 3600 appropriation, excluding sunk costs prior to Fiscal Year (FY) 77. The plan further defines the included and excluded effort in the MED program and the baseline aircraft configuration and performance. Annexes to the plan break down each cost element into detailed subelements; and provide a complete list of the definitions, assumptions, ground rules, and methods of calculating and estimating the cost of each subelement. The means of tracking and reporting the current status vs the DTLCC goal and the cost elements is included, of course. A synopsis of the cost elements is shown in Figure 2.

The DTLCC program not only provides visibility and control of total life cycle cost, but the single DTLCC goal is intended to provide the program manager with the necessary flexibility to achieve this goal. The plan provides a set of conditions and procedures to adjust the MED and Weapon System Cost elements in exchange for significant life cycle cost savings. The program manager will have the authority to trade costs among the four elements within established budget constraints and funding limitations. Potential cost trades which exceed the budget flexibility of the program manager will be brought to the attention of the Air Staff and DOD for resolution. Adjustment of the life cycle cost goal will normally be requested for changes in program direction such as funding profiles, buy quantities, schedules, design requirements, and other factors which are beyond the program manager's control.

FIGURE 2

AMST LIFE CYCLE COST GOAL AND SUBELEMENTS

MED COST	WEAPON SYSTEM COST (WSC)
MED Contract	Aircraft (Total Buy)
ECO Allowance	Support Equipment (Peculiar)
Other Government Costs	Training Equipment
	Data
	GFE & Other Government Costs

OTHER SUPPORT COSTS (OSC)	O&S COST (20 YEARS)
Initial Spares	Fuel
Spare Engines	Base Maintenance
Interim Contractor Support	Depot Maintenance
Facilities Modification	Personnel & Training
Type I Training	Replenishment Spares
Initial Common Support Equipment	Class IV Modifications

$$\text{LCC GOAL} = \frac{\text{MED} + \text{WSC} + \text{OSC} + \text{O\&S}}{277}$$

APPLICATION OF DTLCC IN THE AMST CONTRACT

The AMST program manager will exercise aggressive cost, schedule and technical control of the AMST Program through five management centers, each headed by a project manager. The management centers are: Structures Systems, Flight Systems, Power Systems, Mission Systems, and Flight Test. The project managers will receive subgoals from each of the four DTLCC cost elements. The program manager will control the integration of common cost elements across the management centers. Integration of life cycle cost consciousness at all levels of Air Force and contractor management is a primary program consideration. Contract requirements include the following provisions for DTLCC:

INTERNAL CONTROL - The total contract DTLCC goal and its four cost elements will be established by the Government based on costs proposed by the contractor during competition. The contract DTLCC goals do not include the Air Force program managers' in-house program costs nor his management reserve for potential contract changes. The contractor is required to suballocate the four cost goals throughout the contract Work Breakdown Structure (WBS) to subsystem/component levels at which the impact of discrete design changes on the four cost goals may be identified. Controls and incentives in the contractors' management structure are provided to require designers and managers at each level to consider life cycle costs in key management decisions, in all Engineering Change Proposals (ECPs), and in all design trade studies.

LIFE CYCLE COST TRADE STUDIES - The contractor is required to continually review the program for "cost drivers." Candidates for cost reduction are subjected to a continuous trade study effort to minimize total life cycle costs through such actions as design simplifications, producibility changes, and reliability/maintainability improvements. The contractor's project management structure provides teams of specialists from each functional discipline who systematically review each trade study candidate for significant life cycle cost reductions. The reviews also point out Government requirements and policies which contribute to higher costs. The contractor implements those design changes which are within his budget flexibility. Changes to cost goals which are "out of scope" are submitted to the Air Force program manager for a decision.

STATUS ASSESSMENT AND REPORTING - The contract specifies the methodology and models to set cost goals and to track the life cycle cost status of the four cost elements and each suballocation. The contractor is required to continuously track and to periodically report the detailed life cycle cost status. He is also required to document, track, and report all design changes made to reduce life cycle costs. Development and production costs must be reconciled with the contractor's validated accounting system (Cost/Schedule Control System). Government teams periodically visit the contractor to review and validate his entire DTLCC management system. The contractor provides special reviews to support Air Force program validation milestones with the Department of Defense.

INTEGRATION - Design to Life Cycle Cost consciousness has been woven into almost every aspect of the program. The contractor's internal management structure, along with the Air Force program office, is specifically geared to provide appropriate information and incentives for each organizational level to consider cost on an equal basis with technical requirements and schedule. The program office has developed a computerized model to estimate production costs. In minutes it can provide a detailed cost estimate of proposed changes to the aircraft or the program schedule. An essential asset to DTLCC is an O&S cost model which was developed by the program office with the assistance of the using and supporting commands.

OPERATING AND SUPPORT COST FORECASTING

The ability to accurately forecast Operating and Support (O&S) costs is the key feature which permits the evolution from "Design to Cost" to "Design to Life Cycle Cost." Previous attempts at O&S cost forecasting have used parametric models which were insensitive to design changes. Other models, such as the Logistics Support Cost (LSC) model, use statistical techniques to forecast support costs for individual aircraft components. The LSC model has proven quite useful in identifying component support costs, but fails to account for interactions as the components are integrated into a complete aircraft system.

Air Force regulations (AFR 173-10) specify use of the Cost Analysis Cost Estimating (CACE) model for analysis of O&S costs. The CACE model is basically an accounting structure which combines a multitude of system level maintenance inputs, rates, and average costs to sum up the annual operating and support cost for a squadron of aircraft. The regulation contains input values which are regularly updated for inventory aircraft based on historical, budgeted costs. For acquisition aircraft, most program offices contractually apply the LSC model and, using its component level costs, attempt to translate this data to the system level inputs of

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the CACE model. As actual costs become available, significant differences are often found for which correlation is difficult or impossible.

THE AMST O&S COST METHODOLOGY - The AMST program office has developed a unique approach to O&S costing. This approach adapts the basic accounting structure of the CACE model and uses a variety of means to calculate the input values. The AMST CACE model inputs are categorized into three areas: Air Force Standard Inputs, Program Standard Inputs, and Design Sensitive Inputs. A summary of the inputs and a sample output run are shown in Tables 1 and 2 respectively.

Air Force Standard Inputs. Input values such as pay rates, fuel cost per gallon, and training costs are taken directly from AFR 173-10. These values are based on Air Force wide statistical averages and are updated regularly.

Program Standard Inputs. Input values such as programmed flying hours and crews assigned per aircraft are stated in the MAC ROC and approved by USAF Headquarters. To digress for a moment, the Air Force calculates O&S cost based on peacetime operations. Elements such as maintenance manning and spares stockpiles, however, are based on planning factors for wartime operations. For example, the AMST CACE model output is based on a standard Air Force equation which uses such inputs as maintenance manhours per flying hour, wartime utilization rates, and wartime efficiency factors to compute maintenance manpower and its associated costs.

Design Sensitive Inputs. The heart of the AMST CACE model is the manner in which it computes the design sensitive inputs. Such values as depot maintenance cost, replenishment spares, and maintenance manhours per flying hour are computed from a "bottoms-up" engineering analysis. A detailed work unit code listing breaks these items and tasks down to a level where the work can be scoped or compared to historical data. As actual data becomes available, it is accumulated and

TABLE 1

AMST CACE MODEL INPUTS

Air Force Standard Inputs	Unit of Measurement	Source
Pay & Allowance Cost	$/Manyear	AFR 173-10
PCS Cost	$/Manyear	"
Medical Support Cost	$/Manyear	"
Training Cost	$/Graduate	"
Personnel Acquisition Cost	$/Man	"
Personnel Turnover Rates	Percent Per Year	"
Vehicular Equipment Cost	$/Manyear	"
Fuel Cost	$/Gallon	"
Class IV Aircraft Modification Cost	$/Unit Flyaway Cost	"
Program Standard Inputs		
Assigned Aircraft	Aircraft/Squadron	MAC ROC
Peacetime Aircraft Utilization Rate	Flying Hours/Year/Aircraft	"
Wartime Aircraft Utilization Rate	Flying Hours/Year/Aircraft	"
Crew Ratio	Crews/Aircraft	"
BOS/RPM (MAC)	$/Manyear	AFR 173-10
Design Sensitive Inputs		
Unit Flyaway Cost	$/Aircraft	Production Cost
Aviation Fuel Consumption Rate	Gallons/Flight Hour	Model
Maintenance Manhours Per Flying Hour	MMH/Flight Hour	Model
Base Material (Variable Cost)	$/Flight Hour	AFR 173-10
Base Material (Fixed Cost)	$/Aircraft/Year	AFR 173-10
Depot Maintenance (Variable Cost)	$/Flight Hour	Model
Depot Maintenance (Fixed Cost)	$/Aircraft/Year	Model
Replacement Support Equipment	$/Aircraft/Year	AFR 173-10
Crew Composition	#, Type	Aircraft Specification

Source: AMST O&S Cost Estimating Handbook, 15 September 1977.

TABLE 2

AMST CACE MODEL OUTPUT
(SAMPLE ILLUSTRATION)

ANNUAL SQUADRON OPERATIONS & SUPPORT	COST
Recurring Investment & Miscellaneous Logistics	
Common AGE (Including Spares)	$ XXX XXX XX
Aviation Fuel	X XXX XXX XX
Aircraft Maintenance, Base Level (Material Only)	X XXX XXX XX
Aircraft Maintenance, Depot Level	X XXX XXX XX
Modification, Class IV (Including Initial Spares)	XXX XXX XX
Munitions, Training	0
Replenishment Spares	XXX XXX XX
Vehicular Equipment	XX XXX XX
Subtotal	X XXX XXX XX
Pay & Allowances	
Military Pay and Allowances	X XXX XXX XX
Civilian Pay and Allowances	XXX XXX XX
Subtotal	X XXX XXX XX
MFP - BOS/RPM Support Of	
PPS Manpower	XXX XXX XX
BOS/RPM Manpower	XX XXX XX
Subtotal	XXX XXX XX
Medical (MFP VIII) Support Of	
Medical Officers	XX XXX XX
Medical Airmen	XXX XXX XX
Subtotal	XXX XXX XX
Personnel Support	
Permanent Change of Station - Officers	XXX XXX XX
Permanent Change of Station - Airmen	XXX XXX XX
Subtotal	XXX XXX XX
Pipeline Costs	
Officer Acquisition - Pilots	XXX XXX XX
Officer Acquisition - Nonpilot Aircrew	XX XXX XX
Officer Acquisition - Nonaircrew	XX XXX XX
Airmen Acquisition	XXX XXX XX
Officer Training - Pilots	XXX XXX XX
Officer Training - Other Aircrew	XX XXX XX
Officer Training - Nonaircrew	X XXX XX
Airmen Training - Base Level Aircraft Maintenance	XXX XXX XX
Airmen Training - Other	XX XXX XX
Subtotal	X XXX XXX XX
TOTAL ANNUAL COST ESTIMATE	$XX XXX XXX XX

summed through this same structure, making comparisons simple.

Aviation fuel gets special attention. A detailed set of mission profiles were developed in cooperation with the Military Airlift Command. The aircraft is analytically "flown" through these profiles to determine statistical composite fuel consumption rate. The model shows excellent correlation to data on existing aircraft. An added benefit is the capability to point out the sensitivity of fuel costs to planned operational and training concepts.

Other inputs such as base material and replacement support equipment costs are presently scaled to similar aircraft operating in a comparable environment. Continued effort is planned to develop design sensitive methodologies for these values.

CONTRACTUAL APPLICATION OF THE CACE MODEL - The AMST contract requires application of both the basic CACE model and a fleet CACE model to compute O&S costs. The fleet model is an extension of the basic model which considers such factors as force buildup and phaseout, squadron location, and spares provisioning schedules to compute 20 year O&S cost for the total AMST fleet. Both models are controlled by the program office. Adjustments to the baseline estimate are based on contractor design changes which do not affect the basic assumptions and groundrules in the model. The contractor is also required to use the LSC model to assess logistics support cost in trade studies at the component level.

CONCLUSION

The AMST Design to Life Cycle Cost concept should help to alleviate the "eleventh hour" surge of introducing logistics considerations late in the program. It is basically a sound economic concept in that it attempts to focus design decisions on the difference in total cost of the alternatives.

The AMST Design to Life Cycle Cost program has been endorsed by both Air Force Systems Command and Air Force Logistics Command as a "significant step forward in implementing the concepts of DOD Directive 5000.28." Certainly, it achieves a focus on life cycle costs unattainable with previous techniques.

REFERENCES

[1] AFR 173-10, USAF Cost and Planning Factors, 6 Feb 1975.

[2] AFLCP/AFSCP 800-19, Joint Design to Cost Guide, 11 Jun 1976.

[3] C-14/15 Design to Life Cycle Cost Plan, 3 Aug 1977.

[4] C-14/15 O&S Cost Estimating Handbook, 15 Sep 1977.

[5] Department of Defense Directive 5000.28, Design to Cost, 25 May 1975.

MULTI-PURPOSE PREDICTIVE ESTIMATING TECHNIQUE (MuPPET) FOR ASSESSMENT OF ADVANCED SYSTEMS

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INTRODUCTION

This paper describes a new method for assessing the potential effectiveness and cost of advanced concepts. The methodology is intended for very early pre-program or program application when conventional data is scarce or lacking.

During the mission need analysis and concept formulation phases of new programs, typical available data and information are vague, incomplete, and largely qualitative. This is especially true if advanced technology options are viable candidates to meet mission needs. This type and quality of data defies inclusion in "traditional" determinant, statistical, and/or stochastic models. In spite of this dilemma, system evaluators must make decisions about technological and cost constraints, and rank the comparative worth of competing options.

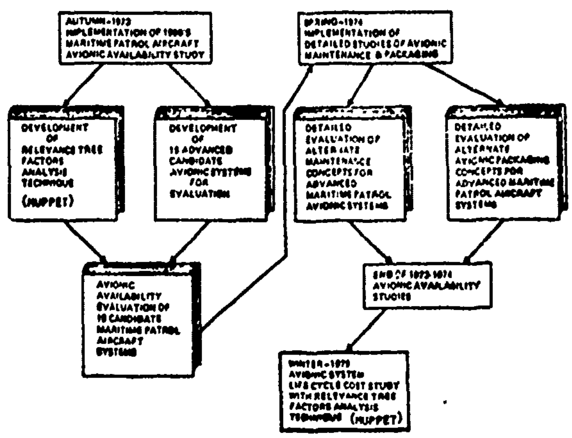
This problem has been recognized for some time. In 1973, Boeing implemented a search for existing analytical tools appropriate for very early evaluation of the cost/effectiveness of competing system options. One hundred sixty documents and fourteen computer programs pertaining to life cycle cost and system effectiveness were reviewed. Results of this study indicated that as of the end of 1973, a practical method of determining life cycle cost early in a program's life cycle did not exist. Information pertaining to system worth was almost non-existent. Since that time much work has been done in the cost/effectiveness area, but as yet, a standard technique for determining system worth during the early stages of a program has not been commonly accepted and used.

High level policy directives to develop early analyses have not been lacking. In February 1976, William P. Clements, Jr., then Deputy Secretary of Defense, issued a memo to the Secretaries of the military department (1) which directed the departments to focus now on reducing the outyear operations and support costs of new systems under development. In April 1976, the Office of Management and Budget issued Circular No. A-109 (2) which gave all government agencies policy direction on the acquisition of major systems. This Circular called for a pre-program phase during which a specific mission need would be established and defined prior to commitment to a specific system concept to fulfill the mission. This phase would be followed by a major decision point at which time enough analysis must be done to establish technological and life cycle cost constraints on mission accomplishment. Also, A-109 requires a thorough analysis and evaluation of all feasible alternative systems during the following system concept phase. These directives set a critical requirement for the development of viable tools to accomplish the necessary analyses and evaluations.

Missions which can be accomplished by evolutionary outgrowths of existing technology can usually be assessed by conventional parametric estimating techniques which extrapolate from an existing historical data base. When new revolutionary technology is involved, however, an unconventional estimating technique must be developed which can accept preliminary, incomplete data; normalize them to a common basis and credibly predict expected costs and effectiveness. Boeing has developed such a methodology in the Multi-Purpose Predictive Estimating Technique (MuPPET).

MuPPET MODEL DEVELOPMENT

The model was developed in its initial manual form in late 1973, and was used to assess the expected impact of revolutionary technology on the operational availability of avionics in the 1980-2000 time frame. Results from this initial application were encouraging and the model was refined and computerized in 1975. It was next used to assess the life cycle cost implications of a fiber optic avionic data transfer system. Exhibit 1 traces this development process.



HISTORY OF DEVELOPMENT AND EXPERIMENTAL APPLICATION OF MuPPET

Exhibit 1

The results obtained from these two experimental applications have led to the conclusion that the model is a useful, credible, and comparatively low-cost tool for assessing and relating the various cost and effectiveness parameters associated with the introduction of new technology.

MODEL METHODOLOGY

MuPPET is a tool for predicting and comparing the cost and effectiveness of alternate solutions for acquiring a required mission capability. The tool was developed specifically for use very early in a program's life cycle when very little is historically known about the hardware system that will result.

The process focuses on one major cost/effectiveness decision variable at a time (such as life cycle cost or system performance) and predicts the impact of the new required capability on this variable. The process is implemented by first identifying the elements of the required mission and the relevant functional issues of the decision variable of interest (for example, life cycle cost). Then the impact of proposed mission solution(s) on the decision variable is estimated within the context of each of these relevant decision issues. The impact estimate for each proposed solution is quantified as an expected departure from the value of the decision variable which results from a "baseline" solution. The baseline must contain sufficient historical data to determine the corresponding value of the decision variable, and may be any known system which performs a somewhat similar mission to the new required mission.

The process utilizes highly structured and disciplined mission solution/decision issue/decision-variable definitions and mathematical transforms to normalize and correlate uncertain, disjoint, and scarce input information. The resultant computer-aided model may be characterized as a three-dimensional estimating matrix as shown in Exhibit 2 where the three mutually perpendicular axes are:

(1) The functional activities or issues relevant to the decision variable required to implement the mission (the relevance tree).

(2) The features of the system solution being considered (the solution definition tree).

(3) The constituent variables of an objective function of interest such as life cycle cost (the criteria set).

Utilizing whatever input information is available, incremental comparative impact estimates are made for each decision cell of the matrix formed by the intersections of the elements on the three axes. Internal weighting and data transform processes within the model normalize and aggregate the incremental input estimates into an overall assessment of the impact of the proposed system option on the decision variable of interest, e.g., life cycle cost, as compared to the known baseline. The elemental input estimates and subsequent transforms leading to this output assessment are traceable and defendable back through the model.

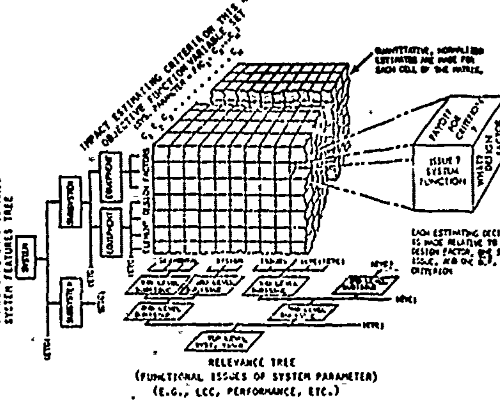


Exhibit 2

To visualize this estimating process, refer to Exhibits 3 and 4. Exhibit 3 portrays the model matrix sliced along the criteria set axis. Each plane thus formed represents the baseline value of each constituent variable (criterion) of the decision variable objective function. The total baseline value of each criterion is composed of incremental values proportionately allocated to each mission-solution element/decision issue combination. These are represented in the exhibit by the intersections on the plane. The positive and negative vectors leading from these intersections represent the estimated impacts on the incremental baseline values resulting from the various mission-solution element/decision issue combinations.

Exhibit 3

A ring around an intersection represents a "no-impact" estimate for that combination (note that the impacts portrayed in Exhibit 3 are examples only and have no relationship to a real problem).

Exhibit 4 portrays the manner in which these elemental impact vectors are summed to an aggregate impact on each baseline criterion value. The last step of this estimation process is to compute the predicted value of the decision variable for the particular system solution under investigation. This is done by evaluating the decision variable's objective function using the impacted values of the constituent variables (criteria) computed above. This objective function may be any mathematical construct which appropriately defines the decision variable in terms of the constituent variables used as estimating criteria within the model.

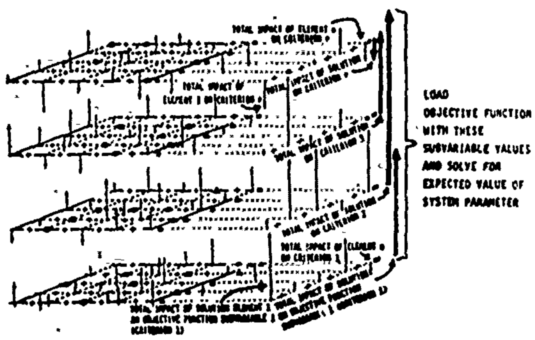
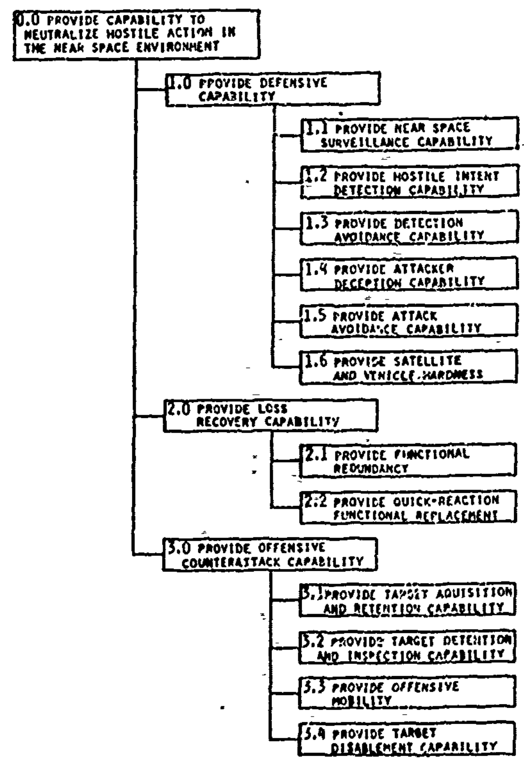


Exhibit 4

EXAMPLE APPLICATION

To illustrate the applicability of the MuPPET process, a suggested phase zero life cycle cost scoping process for a possible future mission is presented. The example mission chosen for this paper is the "Neutralization of Hostile Action in the Near Space Environment". This mission requirement is an example only and is not intended to reflect an actual DoD mission. It was chosen to illustrate a typical advanced technology mission. The analysis procedure presented is based on a mission solution definition in terms of its functional elements and is applicable to phase zero activity leading to the "Milestone 0" decision as required by OMB Circular A-109 (2). Note that one of the most powerful features of the MuPPET process is its usefulness as an estimating tool for the highly aggregated problem structures encountered in the "executive decision environment" of phase zero as well as for highly decomposed, detailed problems and solutions in the "engineering decision environment" of the system concept phase. The same basic model of the problem can be used throughout both phases. This is possible because the technique develops problem and solution definitions through a top-down, successive decomposition approach as a program progresses from preliminary top level decision requirements to lower level system design decision requirements. The life cycle cost (LCC) assessment process for our mission requirement example would proceed as follows:

(1) Define the mission, "Neutralization of Hostile Action in the Near Space Environment", in terms of its functional capability elements. These are the "Mission Element Needs" of the Mission Element Need Statement (MENS) and when related in a categorial structure form becomes the "Solution Definition Tree" of the MuPPET LCC model. Exhibit 5 illustrates this mission element structure. The third level elements on the tree form the solution element axis of the three-dimensional estimating matrix discussed in the previous section. Note that these mission solution elements formulated during phase zero are the take-off points for formulating detailed system concept solution alternatives during the system concept phase.



Solution Definition Tree
Exhibit 5

(2) Identify the relevant life cycle cost issues pertaining to the general mission requirement. Order these issues in a categorial structure to form the "LCC Relevance Tree" of the MuPPET model. Exhibit 6 illustrates this tree decomposed to the third relevance level. These LCC issues can be further decomposed through successively deeper relevance levels, and would be for a detailed analysis of a candidate system design. For preliminary high level decisions such as "Milestone 0", however, two or three levels of decomposition will usually suffice. For our example, the third level issues shown in Exhibit 6 form the relevant issue axis of the model's three-dimensional estimating matrix.

(TOP LEVEL DECISION ISSUE)

- 1-0 PROVIDE ACCEPTABLE LIFE CYCLE COSTS (LCC) FOR NEAR SPACE HOSTILE ACTION NEUTRALIZATION CAPABILITY

  (SECOND LEVEL COST ISSUES)

  - 1-1 PROVIDE ACCEPTABLE PLANNING COSTS

    (THIRD LEVEL COST-ISSUES)

    - 1-1.1 CONTROL CONCEPTUALIZATION COSTS
    - 1-1.2 CONTROL CONCEPT VALIDATION COSTS
  - 1-2 PROVIDE ACCEPTABLE DEVELOPMENT COSTS
    - 1-2.1 CONTROL SYSTEM DESIGN COSTS
    - 1-2.2 CONTROL DEVELOPMENTAL SYSTEM GENERATION COST
    - 1-2.3 CONTROL PRODUCTION DECISION COSTS
  - 1-3 PROVIDE ACCEPTABLE PRODUCTION COSTS
    - 1-3.1 CONTROL PRODUCTION RESOURCE GENERATION COSTS
    - 1-3.2 CONTROL PRODUCTION HARDWARE GENERATION COSTS
    - 1-3.3 CONTROL PRODUCTION HARDWARE DELIVERY COSTS
  - 1-4 PROVIDE ACCEPTABLE DEPLOYMENT COSTS
    - 1-4.1 CONTROL SYSTEM INITIALIZATION COSTS
    - 1-4.2 CONTROL SYSTEM DELIVERY COSTS
  - 1-5 PROVIDE ACCEPTABLE OPERATIONS COSTS
    - 1-5.1 CONTROL DIRECT OPERATING COSTS
    - 1-5.2 CONTROL INDIRECT OPERATING COSTS
  - 1-6 PROVIDE ACCEPTABLE SUPPORT COSTS
    - 1-6.1 CONTROL DIRECT SUPPORT COSTS
    - 1-6.2 CONTROL INDIRECT SUPPORT COSTS
  - 1-7 PROVIDE ACCEPTABLE UPDATE MODIFICATION COSTS
    - 1-7.1 CONTROL UPDATE RESOURCE GENERATION COSTS
    - 1-7.2 CONTROL UPDATE HARDWARE GENERATION COSTS
    - 1-7.3 CONTROL UPDATE HARDWARE DELIVERY COSTS
  - 1-8 PROVIDE ACCEPTABLE RETIREMENT COSTS
    - 1-8.1 CONTROL DIRECT RETIREMENT COSTS
    - 1-8.2 CONTROL INDIRECT RETIREMENT COSTS

LCC Relevan- Tree
Exhibi 6

(3) Develop an LCC objective function pertaining to the general mission requirement. This objective function defines the decision variable of interest (life cycle cost) in terms of a set of constituent variables and their mathematical relationships. Exhibit 7 illustrates the development of the LCC objective function for our example. The constituent variables of this equation are the control criteria of the MuPPET model and as such form the third axis of the three-dimensional estimating matrix. As portrayed in Exhibit 3 of the previous section, the impacts of the solution elements on the LCC issues are estimated in terms of these constituent variables. Total life cycle cost for acquiring and maintaining the required mission capability is then predicted by evaluating the LCC objective function using the aggregated impacted values of these constituent variables. As with solution definition and relevant issue identification, the basic objective function variable set can be decomposed to lower levels of sub-variables as the need arises for more finely detailed evaluations of candidate system designs during later program phases.

LIFE CYCLE COST OBJECTIVE FUNCTION DEVELOPMENT FOR NEUTRALIZATION OF HOSTILE ACTION IN THE NEAR SPACE ENVIRONMENT

LET: LCC = ACQUISITION PRICE + OWNERSHIP COST = AP + OC

WHERE: AP = (NON-RECURRING ACQUISITION PRICE) +...
...+(SUMMATION OVER MISSION LIFETIME OF RECURRING ACQUISITION PRICE)

$$AP = NAP + \sum_{t=1}^{n} RAP_t;\ t = 1,2,\ldots n \text{ LIFE CYCLE YEARS}$$

AND: OC = (NON-RECURRING OPERATIONS COST) + (SUMMATION OVER MISSION LIFETIME OF RECURRING OPERATIONS COST) + (NON-RECURRING SUPPORT COST) +...
...+ (SUMMATION OVER MISSION LIFETIME OF RECURRING SUPPORT COST)

$$OC = NOC + \sum_{t=1}^{n} ROC_t + NSC + \sum_{t=1}^{n} RSC_t;\ t = 1,2,\ldots n \text{ LIFE CYCLE YEARS}$$

THEREFORE: $$LCC = NAP + NOC + NSC + \sum_{t=1}^{n} (RAP + ROC + RSC)_t;\ t = 1,2,\ldots n \text{ LIFE CYCLE YEARS}$$

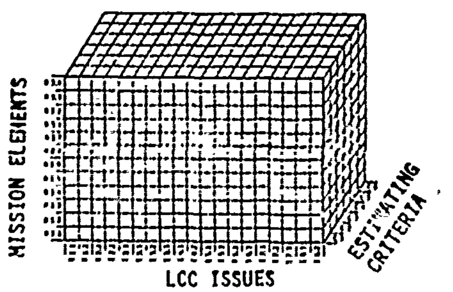
IF:

NAP =	COST EVALUATION CRITERION 1	= C1
NOC =	" " " 2	= C2
NSC =	" " " 3	= C3
RAP =	" " " 4	= C4
ROC =	" " " 5	= C5
RSC =	" " " 6	= C6

THEN: $$LCC = C1 + C2 + C3 + \sum_{t=1}^{n} (C4 + C5 + C6)_t;\ t = 1,2,\ldots n \text{ LIFE CYCLE YEARS}$$

Exhibit 7

(4) Code the 3-dimensional estimating matrix representing the elements of the required mission (from 1), the relevant LCC issues (from 2) and the LCC evaluation criteria (from 3) into the existing computerized matrix structure of the general MuPPET model. This matrix, along with the preprogrammed data processing packages of the model, constitute the basic computerized MuPPET model to be used to evaluate life cycle cost of the example mission capability. Exhibit 8 illustrates the example matrix.



EXAMPLE MODEL MATRIX
Exhibit 8

Note that as the program progresses into the system concept phase and alternate mission system candidates are defined and evaluated in the model, only the solution definition axis of the basic estimating matrix changes from concept to concept. The relevant LCC issues and objective function variables are generic in nature and are independent of the alternate systems' characteristics. The LCC issues and objective function variables may, however, be decomposed to lower levels of detail as the need for more accurate estimates arises. This increasing accuracy is achieved by decomposing the required higher level impact decisions into many small lower level decisions so that the focus of each individual decision is narrowed relative to the decision data base available. Also, a decision error at a low elemental level will inject less error into the overall estimate than an error at a more highly aggregated decision level.

(5) Develop baseline LCC values for each cell of the matrix and load into the model. The baseline values for our example would be derived from known data on existing mission capability elements which are similar to or can be correlated with the required mission capabilities.

(6) Develop appropriate relative weightings for each criterion/issue combination and load into the model. These weight values are derived through a highly structured process within the MuPPET methodology and portray the strength of the relationships between individual LCC criterion and decision issues.

(7) Estimate the incremental LCC impact of each matrix cell by estimating the departure from its baseline value caused by the likely characteristics of the solution element under consideration. These incremental impacts are quantified and loaded into the model through a formal estimating and normalizing process within the MuPPET methodology to assure consistency and traceability of inputs.

(8) Exercise the model to obtain an aggregate output estimate of the likely life cycle cost consequences of acquiring and maintaining the capability to "Neutralize Hostile Action in the Near Space Environment".

The foregoing eight-step procedure illustrates the end-to-end process that would be required to apply the MuPPET methodology for life cycle cost assessment of our example mission need in preparation for a "Milestone 0" decision. The same basic process could be utilized to provide estimates for other decision variables required by this milestone.

SUMMARY AND RECOMMENDATIONS

The foregoing discussion of the development and suggested application of the MuPPET process is intended to give the reader a preliminary introduction to the potential and general structure of the methodology. An in-depth treatment of the heuristic, mathematical and computer processes involved is not within the scope of this paper and has been avoided. Interested readers who would like to investigate our technique in greater depth are encouraged to obtain the documents listed in references 3 through 6 or contact the authors.

We believe that the tool can be a useful aid in establishing the likely magnitudes of various decision variables and in performing trade-offs during phase zero activity. However, to establish the usefulness and accuracy of the tool in a non-experimental situation, it is recommended that the model be tested and validated by application to some existing "evolutionary" procurement where its results may be compared to conventional cost/effectiveness tracking tools already in use.

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A MULTI-STAGE ANALYSIS OF DESIGN-TO-COST

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ABSTRACT

An important motivation for implementing financial incentives in systems acquisition is the growing cost of major systems and the ongoing and anticipated decline of real dollars available for design, development, and production of these systems. The purpose of this research is to examine the optimal structuring of internal financial incentives, such as Design-to-Cost, as a vehicle for cost control. A review of the theoretical literature on incentives and decision processes underlying this issue reveals the somewhat surprising result that only very simple two-level, static analyses of contractual and internal incentives have been undertaken to date. This paper generalizes previous research and develops a theoretical framework for providing insights into the following (as yet rather incompletely addressed) issues:

a. How long should competitive parallel development (if it is used at all) proceed before awarding a single-source contract for further development and production?

b. What are the effects of perceived multistage rewards (e.g., follow-on contracts) on contractor behavior, on DOD and responsible Service behavior?

c. What are the effects of a multi-level determination of contract parameters? (For example, in Design-to-Cost, the overall project budget is negotiated with Congress, performance levels are set by DOD-Service, and cost allocation and contract coordination is the responsibility of a Project Management Staff).

d. How do risk and contingent contract renegotiation enter in an optimal contract design?

Basically, the framework developed envisages development and a production stage to the system life cycle, where it is assumed that development contracts are cost-plus and production contracts are (negotiated) general incentive contracts. A number, say "n," of contractors is assumed to take part in parallel development activities, the outcome of which is a prototype system having certain performance characteristics which depend (stochastically) on the effort expended by contractors during the development stage. The firm with the best design is then allowed to bid on a production contract, which is assumed negotiated (as a Pareto point depending on relative government/contractor bargaining power) as a general incentives contract. The "n" preselected firms are assumed to play a multi-stage game in determining their level of effort in the development stage. Under simplifying assumptions on the nature of the random elements and the structure of follow-on rewards, the Nash point to this game can be determined and questions of the type raised above can be examined. Some illustrative numerical results are given and a discussion of empirical data further clarifies the possibilities of the framework presented.

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A STRATEGY FOR STIMULATING ENERGY CONSERVATION BY DEFENSE CONTRACTORS

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BACKGROUND

The energy issue has become "energized" by numerous individuals and agencies within the federal bureaucracy---to the extent that every manager at every level, in and out of the government, is under pressure to make a program out of energy. This is in some ways unfortunate, because it can screen some important realities which are necessary to deal effectively with the problem, without an excessive amount of wasted effort. The approach outlined in this paper was based on the premise that "energy" is a factor of production and an economic good. As an economic good, it is relatively scarce and relatively costly. The problem that we are dealing with is that the cost is increasing significantly. Shortages may develop in the near future due to lack of electrical generating capacity or in the longer term due to source energy depletion, but this is really beyond the horizon of the defense contract manager and beyond his control. Contingency planning is about the only effective response that can be made.

More could be said, but the premise that the rising cost of energy is the major problem in defense procurement can be held evident. Related to this premise is the contention that the best way to deal with the problem is to rely on the organization and talent that already deals with the problem of escalating costs of factor inputs used by a given enterprise. If an enterprise conserves energy, it saves money. But, if energy conservation efforts are in themselves too costly, the only benefit is to delay for a brief time the day sometime in the future when the necessary energy supply runs out. However, instead of dealing with energy conservation in terms of generalities, the approach in this paper is, in the first part, to relate experiences of the authors in developing an energy conservation initiative for Air Force industrial plants. The next part describes the specific techniques developed to analyze building energy use and identify specific conservation opportunities. Next, the case for use of computer simulation tools for building energy analysis is presented. The concluding part draws on the authors' experience to date and proposes a strategy for fostering energy conservation among defense contractors.

ENERGY CONSERVATION IN AIR FORCE-OWNED PLANTS

In November 1976, officials in the Directorate of Manufacturing at ASD approved an initiative to promote energy conservation at the 23 government-owned/contractor-operated (GOCO) industrial plants managed by the Directorate.

The primary motivation for this initiative was experience with the emergence of the environmental protection program about 3½ years earlier. The initiative was attended by resolve to anticipate or at least keep up with the shower of directives that seemed inevitable, instead of reacting to events and decisions attended by compressed time schedules. Subsequent events have demonstrated the prudence of the decision to get prepared early. It has been said that the technical basis for decision-making must come from the level of an organization where the knowledge resides. One might add that it usually takes more time for the knowledgeable people to obtain and organize technical data than is allotted for decision-making. The message for organizations with technical responsibilities is---anticipate decisions that will have to be made and invest time and talent to get ready to support that decision-making.

The ASD initiative for GOCO plants preceded the issuance of Executive Order 12003 (20 July 1977) by several months. By this time, an organized effort was already well underway for the Air Force GOCO industrial plants. Probably because the effort was able to unfold without external pressures or arbitrary constraints, all of the issues in the Executive Order (EO) were addressed and specific strategies for dealing with these issues were becoming well developed. The real payoff, however, was the leverage that was available in obtaining the resources and management and industry support needed to sustain the effort.

The policy basis for the energy conservation effort for the GOCO industrial plants is the above-mentioned EO 12003. The Order lays out the blueprint for energy conservation within the federal government. The mandate in the Order impacts two areas: (1) fuel economy of motor vehicle fleets and (2) energy conservation in federally-owned or leased buildings. Of course, it is the federal building directives, which bear on GOCO industrial plant management. The Order requires, as part of a ten-year program, an energy survey of all federally-owned or leased buildings of 5,000 square feet or over. The purpose of this survey and subsequent analy-

sis is to identify cost effective measures, including capital investment, to reduce 1975 energy consumption in office buildings, commercial buildings, and warehouses by 20% by 1985. Although the 20% goal does not apply to all industrial type buildings, conservation is essential.

The 23 Air Force GOCO industrial plants, operated by 28 contractors, support a variety of manufacturing operations such as, aircraft, engines, missiles, electronics, forgings and extrusions, and various system components. Production at these plants is not limited to Air Force hardware. Output is also delivered to Army, Navy, DSA, and NASA customers or their subcontractors. Some civilian production is also permitted; especially in the area of production of aircraft quality forgings. The complex of GOCO plants consists of about 850 buildings, 309 of which are over 5,000 square feet in area. Industrial-covered floor space amounts to about 32,000,000 square feet. Half of this plant area was constructed prior to 1946; ninety percent was constructed prior to 1951.

The contractual arrangements governing the GOCO plants are of significant interest. The basic contractual vehicle is the facilities contract. The facilities contract establishes terms for use of the facilities, protection of the facilities, and upkeep of the facilities. However, the only work paid for under the facilities contract is work involving capital improvements (such as expansion, modernization, or capital type rehabilitation). The contractor writes the checks for recurring maintenance, plant protection, and for utilities and other energy supplies. These expense items become elements of overhead which are allocated to all contracts in the plant as overhead. It is clear, however, that whoever makes these payments, the customer ultimately pays for all costs of manufacturing and facilities operations when dealing with any going concern. Under the existing arrangements, especially where the government is the only customer, this can lead to circumstances that make the need for energy conservation in defense procurement even more urgent. This makes reference t ne fact that defense contractors' costs for nergy are part of overhead. This means that, when the accounts are all settled and all bills are paid, the customer has not only paid the acquisition cost of energy, but also an increment of profit and corporate general and administrative expense. This, of course, sweetens the pot if savings in energy costs are experienced. It also adds to the penalty if the challenge of energy conservation is not met.

The situation at the outset of the ASD energy conservation effort found the GOCO contractors making varying amounts of progress in energy conservation. Committees had been established and employee programs were fairly well structured. The so-called waste-not-want-not measures had been undertaken. A few plants had installed equipment to control peak electrical demand to keep utility demand charges down. There was little evidence, however, of any extensive engineering effort to identify conservation opportunities in any rigorous way. Building retrofit projects, involving capital investment, were seldom identified. Moreover, since capital investments required Air Force funding (which was not available), the lack of funding action discouraged subsequent proposal effort. It might also be noted that projects that were submitted were often based on implicit judgments rather than comprehensive engineering analysis. This was the trend that needed to be reversed to respond to the goals of EO 12003.

In developing an energy conservation program for the GOCO plants, there were three approaches considered. One alternative was to put together a team of qualified specialists to make energy audits for all the GOCO plants and identify conservation opportunities for contractor action and Air Force funding. This approach showed little promise because the experts needed were simply not available. If they were, it seemed clear that they would have to go into each plant a relatively few times, obtain necessary data by "brute force", then develop a terminal report or recommendation. There appeared to be no prospect of substantial, continuing energy management under this alternative.

A second alternative would involve retaining qualified architect engineering firms on a consulting basis to do the same task. This was the basic approach used by ASD in response to environmental regulation impacting the GOCO plants. Based on information provided by the Department of Energy (DOE) sources, energy surveys by consultants would be expensive (15¢ to 25¢ per square foot). Under this approach obtaining funds for surveys appeared to be a difficult proposition and much time would be lost. The limitations of the first alternative were also evident.

The third approach recognized that the basic information about a facility and the way energy was used in that facility would come from the operating contractor. The concept was then developed of inducing the operating contractor to analyze the plant and its operations and identify energy conservation opportunities for his own implementation and for Air Force capital investment. Expertise not available within the operating contractor's staff would be retained only as a last resort, and whenever possible, in connection with the design of specific retrofit projects subsequent to approval of the project for implementation via the facilities contract. It was recognized under this approach that the skillful use of talents of DoD and contractor personnel already on the job in facilities management, plant engineering, financial management, and

other areas, could result in a pool of knowledge and expertise that could support energy management on a continuing basis. The major task then became one of convincing the plant operators to play the game after ASD had come up with a game plan that would work. Getting the plant operator to play the game involved three factors: (1) developing a feasible program strategy, (2) developing confidence in the ability of the Air Force team to do its part, and (3) establishing credible prospects of adequate funding. The job of getting funds support involved demonstrating to Air Force headquarters that a feasible program strategy was in hand and that ASD was able to support a meaningful program. It is not the purpose of this paper to retrace the steps to the present posture. The present posture is that ASD has been provided FY 1978 funding and a commitment for FY 1979 funding when plans anticipated a program for FY 1980. Also, the GOCO plant operators are cooperating in the program as herein described. The purpose of this paper is to inform the defense community about the feasible program strategy that has been adopted for the GOCO plants and to suggest some useful applications of the strategy to defense procurement in general.

ASD BUILDING ENERGY ANALYSIS TECHNIQUES

The following steps comprise the ASD approach to identifying energy convervation opportunities (ECOs): (1) set priorities for analysis effort, (2) define the way energy is currently being used in selected buildings, (3) identify candidate ECOs, (4) analyze impact of each ECO on building energy use, recognizing priority of retrofit actions, (5) perform an economic analysis of candidate ECOs, and (6) implement ECO program. The following commentary on each of these steps should be helpful.

SETTING PRIORITIES FOR ENERGY ANALYSIS

How does one identify plants and buildings which represent the best opportunities? The ASD team reviewed numerous schemes for establishing energy conservation programs and found a common thread running throughout all of them. In each program, a facility survey of some kind is made to see how and where and how much energy is being used. Opportunity analysis is then performed, focused on the most energy intensive areas. Finally, there is an economic analysis to set priorities. The ASD initial facility site survey and building selection procedures are based on the methods outlined in the Department of Energy Site Energy Handbook (ERDA 76/131) and Building Energy Handbook (ERDA 76/163). This basis was selected for the following reasons: (1) the procedures acknowledge that the information base for analysis can best be provided by the operator of a facility, not by a consultant, (2) the procedures in the Handbooks are flexible enough to dovetail with on-going contractor energy conservation programs, (3) the opportunity listings in the Handbooks are very comprehensive and are excellent idea generators, (4) forms for documenting facility energy data in an organized manner are furnished. This eliminates a very large administrative burden on the plant operator's engineering staff.

Using the above technique, the survey of energy consumption at each plant site and the selection of buildings for detailed analysis has presented little difficulty. The only problem has been with facilities that are only partly government-owned and separate utility metering is not provided. Building selection on the basis of square footage (5,000 square feet or over) is the logical approach in most plants. Exceptions noted involve (1) situations where a number of very similar buildings involve a significant combined energy use and (2) one or two plants where energy use in buildings is secondary to overall site energy use. In these instances, primary reliance will be on the Site Energy Handbook approach.

DEFINING CURRENT BUILDING ENERGY USE

The initial premise of the ASD team was that it is absolutely essential to define the baseline energy use conditions in a selected building before the effects of introducing an ECO in the building can be accurately computed. The DOE Building Energy Handbook recognized this fact and provided the forms and computational guidance necessary to do the job. In the words of one plant operator, "It's all in there." However, increasing familiarity with the amount of effort involved led to increasing doubts that plant operators could afford to devote the amount of engineering time needed to perform the "number-crunching" involved in analyzing the baseline condition and evaluating ECO alternatives using manual desktop methods. It was obvious that a powerful tool was needed. The need to use the computer was evident and a computer program was needed that could define the baseline energy condition, test energy and cost implications of alternative ECOs, and preserve the baseline data for future use.

A program was found to suit this purpose---The Building Loads and System Thermodynamics Program (acronym BLAST). The program was developed by the U.S. Army Construction Engineering Research Laboratory (CERL) in response to a requirement from the Air Force Civil Engineering Center. When it became evident that this tool would do the job, the concept of using the Building Energy Handbook to define the energy baseline was abandoned. The handbook will now be used to help the plant operator document building information needed for the

detailed analysis (Building Questionnaire, Building Energy Handbook, (Vol II, Chap 2, Form 2-2). Armed with this analysis the operator will use the ECO checklist (Building Energy Handbook, Vol II, Chap 2, Form 2-3) to identify potential ECOs. At this point, instead of using the manual calculation approaches in the handbook, the BLAST computer model or an equivalent model is employed. The BLAST program is currently available on the Control Data Corporation Cybernet time share service for commercial or GSA contract use. The program has been locally evaluated in a study conducted at WPAFB and found to be very effective. The GSA apparently shares this opinion because it has selected BLAST for use in energy analysis of GSA buildings

How is BLAST used to define the way energy is used in a building? The BLAST program estimates, hour-by-hour for any given year, the space heating and cooling requirements of a building, performance of air handling systems, and performance of central heating and cooling plants. This estimate is based on extremely rigorous and detailed algorithms used to compute building thermodynamic loads and system performance. The input language is English-like rather than computer-like. The program contains a very extensive library of engineering standards which frees the user from the tedious task of inputting hundreds of numbers for each space or building. In layman's terms, BLAST is used to create an "as built" model of the building which portrays the energy use patterns of a building.

IDENTIFYING ECOs

The basic process of identifying ECOs employs the survey checklist in the DOE manuals, augmented by the building operator's own experience and engineering insight. Opportunities, as developed, must be analyzed in terms of capital cost, operating and maintenance (O&M) cost impact, and performance characteristics. The next step is to try the ECOs out against the baseline condition.

ANALYZING IMPACT OF ECOs

Investigation of an ECO, after simulating the basic building energy profile, can be accomplished by making a simple input data change, then running the BLAST model to assess the effect of the change. The value of such a tool to facility engineering management cannot be overstated since the files created in the BLAST program can be saved on disc or tape. This means that effort expended once, if kept up to date, can be used throughout the life of a building. The implications of having this engineering tool available are suggested by the following extract from the ASD BLAST training material: "(1) You want to add a partition from floor to ceiling in a building zone. A simple input change to the already constructed files can tell you the effect of that partition on your energy picture in the building. (2) You want to investigate a potential increase or decrease in production on your utility bill. Maybe you would like to add a shift. Simply change the occupancy, lighting and equipment schedules for your already constructed building load simulation files and let the computer do all the heavy work. (3) You want to investigate the overall effect of changing the throttling range of your plant's thermostats. This is a simple 20 minute exercise if the building simulation is already constructed. (4) The sensitivity analysis capabilities of the program make it a shoo-in for definition of automated Energy Management Control Systems. You can investigate such potential benefits as zone lighting control or air handler cycling before laying out any hard cash for system design. You can investigate the impact of equipment maintenance problems and determine the benefits of central monitoring capability. (5) Speaking of O&M, the engineer who prepares the program input data will become intimately familiar with the operation of building systems. The impact of seemingly small deficiencies such as inoperative or partially inoperative outside air dampers will become readily apparent as related to the total energy picture for a building. He will be in a position to recommend O&M procedures that cost little or nothing to implement but have tremendous potential for energy reduction."

ECONOMIC ANALYSIS OF ECOs

The economic analysis of ECOs is performed on a life cycle costing basis, using the procedures specified in the DOE Life Cycle Costing Emphasizing Energy Conservation Handbook (ERDA 76/130). The calculations required by this handbook are extensive, necessitating more computer help. A computer model, LIFCY-2, has been obtained from the DOE to support the computation effort. LIFCY-2 provides the capability to compare economic implications of several ECO alternatives. Sensitivity analysis can also be easily performed to assess the effect of alternative future conditions on the life cycle cost of an ECO.

IMPLEMENTATION OF ECOs

Limitations on this paper prevent devoting extensive discussion to the implementation of ECOs determined to be cost effective. The analysis provides excellent support for budget action, as the ASD experience has demonstrated. Funds appropriated will be obligated under the applicable facilities contract. The informa-

tion base developed during the analysis phase ensures an audit trail which will be used by field pricing and audit personnel to ensure that the energy cost avoidance does accrue to the Air Force or other Government customers for the life of the ECO.

A STRATEGY FOR PROMOTING ENERGY CONSERVATION

The first question that comes to mind in considering a program strategy applicable to defense contractors in general is, "Why can't it be done the same way as the GOCO plant program? Everything can be done, in fact should be done, in the same way until the economic analysis is reached. Here is where the difference becomes evident. In the GOCO plant program, the customer is making an investment based on a cost-benefit analysis of customer return on the capital the customer provides. The operator participates to the extent required because of prospects of somewhat improved competitive posture and other peripheral benefits. Now if the contractor owns the plant to be retrofitted, his decision to provide the capital to undertake energy projects is based on economic analysis, which portrays the contractor's return on investment. Benefits to the contractor in this analysis involve consideration of two key questions: (1) How much of the project benefits will the contractor enjoy versus benefits accruing to the customer. (2) Will the project provide satisfactory return on investment, which now considers the tax implications? It can be seen that the Government, as customer, also can (and should) develop an economic analysis portraying the customer benefits that will result from the contractor's investment opportunity.

If this comparative analysis is done, the basis for decision-making becomes clear. If the investment is attractive to the contractor and beneficial to the customer, the contractor should be encouraged to make the necessary investment. No further incentive should be needed. If the investment is attractive to the contractor but cost benefit to the customer is negligible, encouragement would also be in order, but primarily based on support of the overall Government interest in energy conservation. The crux of the strategy is to deal with those opportunities that involve substantial cost benefit to the customer but a share to the contractor which is insufficient to justify investment. There is no way of estimating what percentage of opportunities would involve this kind of disproportionate prospect of return. The authors are of the opinion that the patterns of forward overhead pricing and incentive contract sharing in defense contracting have created this situation in a majority of cases. There are numerous tactics available to the defense contract manager which can adjust the incentives involved in a particular contract situation to obtain the benefits of contractor investments to reduce energy consumption. New tactics may have to be developed. Although the crux of the issue is the incentive for investment, a task that is almost as challenging is the job of getting a contractor to institute an effective program in the first place. One alternative would be to encourage and educate contractors to undertake energy management programs on a voluntary basis. This approach has probably done some good, but if contractors fail to see a return from their efforts, they will not undertake the kind of effort that is needed. By the same token, if the Government contract manager does not have accurate technical data as a basis for decision, he will be reluctant to entertain any kind of investment incentives. The alternative is to make an energy management plan a contractual requirement in carefully selected circumstances. It is recognized that the DoD has resisted suggestions that energy conservation be made the subject matter of contract clauses. This position has been well-advised because the kinds of provisions proposed were not specific. However, if the methods advocated by this paper were adopted, there would be a very specific deliverable contract item involved that would have a very specific application. There is no panacea. Simplistic approaches can lead to improprieties and waste of resources. However, it is reiterated that the steps that lead up to the crucial investment decision are critical. The job of identifying the investment opportunity and surrounding it by all the facts necessary to guarantee the projected outcome must be done right. The job that must be done is not a management effort. It is not an accounting effort. It is an engineering effort with accountable results that must be properly managed.

A SYSTEMS ANALYSIS PROCEDURE FOR EVALUATING ENERGY REDUCTION ON IPP PROGRAMS

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INTRODUCTION

The Department of the Air Force is responsible for the maintenance of certain industrial capabilities essential to long-term national defense goals. The Industrial Preparedness Planning (IPP) Program is established for meeting these objectives and is designed to maintain an adequate industrial base to support DOD requirements for selected essential military items in a national emergency, in addition to the maintenance of selected industrial segments necessary for the long-term national defense.

Modern technology, the basis for much recent economic growth, has been heavily dependent on energy, especially oil, primarily because of its historically low price. Unfortunately, DOD technology has also followed the trend of being heavily dependent on energy. This requires society to allocate a greater portion of its revenues for energy, which reduces the government tax base, making it difficult to support large DOD budgets. In turn, DOD has less funds for development, but at the same time increased operating costs for facilities because of increased energy prices.

The more fundamental immediate problem examined in this study is that of the effects various degrees of energy reduction will have on supplies and equipment obtained from industry for various Air Force weapons systems. Several specific questions occur, such as how will an energy crisis affect production in IPP plants in a particular region, what are the critical processes and where located, and what is the ability of IPP plants to respond to commitments during an emergency. This study is directed towards responding to these and similar questions.

METHODOLOGY

The Energy System Analysis Procedure (ESAP) is general in nature and represents a broad industrial base. Because the immediate objective was an examination of possible effects or unstable behavior arising from the energy shortage, pertinent factors relating to energy were included in the procedural formulation. Many principal organizational relationships and management policies might have been interesting, but could not be included. However, the critical importance of the structure is the contributing causes to the principal activities, delays, etc., which were included resulting from the flows of energy through the system. These factors included in the system affect the generation of production, shipments, energy, etc.

The ESAP approach follows the same steps that are common to other design techniques. The goals are defined, the significant factors identified, procedure system constructed and tested, and the results analyzed and interpreted. The procedure is designed around a goal requiring a visualized description of the interrelated parts of the system. These verbal statements are translated into mathematical notations which contain the mechanisms of interaction that have been visualized between the various parts of the system.

A system of equations was developed in the context of certain conventions that state how the equations are to be evaluated. These equations control the changing interactions of a set of variables as time advances and are computed periodically to provide successive new states of the system.

The continuous advance of time is broken into monthly intervals. Changes made at the beginning of the interval (month) are not affected by any changes that occur during the interval. At the end of the interval, new values of levels are calculated and from these, new rates are determined for the next interval.

For the purpose of evaluation, the basic equations are separated into flow equations and quantitative equations. For each time step, the quantitative equations are evaluated first, and the results become available for use in the flow equations.

Delay equations introduced a time lag, a conversion process that accepts a given inflow and delivers a resulting flow of output. Many delays are short and their effect is negligible compared with longer delays.

During the process, the relative importance of various factors is determined. Data is obtained relative to changes in value within a range of present operations; obtaining data or refining for operations outside the range would be unjustified as these operations generally are unprofitable.

Even though a great degree of aggregation occurs, energy types, supplies, products, customers and production are segregated in the procedure. Only those items are aggregated that have similar characteristics either in decisions or time response, functions, etc., which preserve the important nonlinearities of the system. Aggregation was based largely by

examining these factors. Individual activities and sequences are formulated in the procedure; therefore, flow diagrams were developed for the sequence of individual actions. This involved paths of events, formations, delays, backlogs, shipments, and production. Through this method, the establishment of aggregation of separate items is possible.

Activity in the procedure consists of interacting flow networks of energy, production, and flow of materials. The materials flow is controlled by many interacting relationships representing information based on inventories, sales, and production. Therefore, those parts are included that directly relate to energy. The omission of other variables from the decisions is not unrealistic, because these influences on decisions seldom take precedence for long if they run contrary to actual energy resource conditions. The procedure has been developed to interpret the response of the system. Thus, concentration is on the main channel of material flow (which includes energy) from production plant to customer and DOD, and on the streams of information flow moving through the systems. The system is concerned with four major types of energy--natural gas, coal, oil, and electricity; therefore, the diagram involves a similar diagram for each energy source. This defines in a general way the problem facing industry when energy supplies are reduced.

The tracing of specific time makes possible the generation of specific time history of the behavior that would result if the system (as described) had actually occurred. It takes the place of the real system and simulates operations under realistic circumstances. This permits a great deal more to be learned because the experimental conditions are fully known, controllable, and reproducible, so that behavioral changes can be traced directly to their causes.

SOURCES OF DATA

Data and information were obtained from interviews with typical organizations participating in IPP programs. A list of these organizations was obtained from the Register of Planned Emergency Producers (Office of the Assistant Secretary of Defense, Volumes I, II, III, DOD 40053-H, April 1975). From this source, twenty-six organizations were pre-interviewed concerning IPP programs, their operations, use, etc. From these a sample was selected to provide data for the ESAP and the case examples presented in the context.

Sufficient information and data existed consisting of descriptive knowledge by management for the study. In fact, management was very sensitive to the preserving of important variables concerning energy and IPP programs; and there was divulged far more useful information than existed in recorded data.

ASSUMPTIONS

The problem of determining the effects of energy on production capacity under varying conditions (especially IPP requirements) is evaluated through an Energy System Analysis Procedure (ESAP). Such an approach is based on several premises:

1. Decisions in management and production take place in a framework of information-feedback systems.

2. Intuitive judgment is generally unreliable about how these systems will change with time, even when good knowledge exists of individual parts of the system.

3. Model experimentation fills the gaps where knowledge and judgment are weakest by showing the way in which the known separate system parts can interact to produce unexpected and troublesome overall system results.

4. Enough information is available for an experimental model building approach without great expense and delay in further data collection.

5. The mechanistic decision-making process is true enough so that the structure of policies and decisions of an organization is represented.

6. The organizational systems are developed to create many of the troubles often attributed to outside and independent causes.

7. Policy and changes are feasible that produce substantial improvement in the behavior and system performance which is often far from what it could be, and initial design changes can improve all segments without compromises or losses from gains in another.

These premises are the basis for developing an approach to the understanding of the effects that energy reductions and changes have on the behavior of IPP production facilities. The interactions between system components are in many situations more important than the components themselves. Therefore, the information feedback becomes the basis for integrating the separate facets of the process.

VALIDATION OF PROCEDURE

Validity of the procedure, ultimate purpose,

and the assumptions underlying the procedure are not separated. The procedure can only be expected to perform to the extent that the system has the characteristics to achieve the goals. In all cases, unknown and uncontrolled forces will develop that will cause events to occur which will affect the long-term outcome, and may or may not influence individual specific events at particular points of time.

The behavior of the procedure is greatly changed if any of the controlling policies are changed. The use of quantitative techniques takes on authenticity; therefore, judgment must be a formal and sound part of the evaluation. Validation does not stop with numerical data but uses both sources including non-quantitative areas.

ENERGY SYSTEM ANALYSIS PROCEDURE (ESAP)

The Energy System Analysis Procedure (ESAP) describes the manufacturer's behavior during energy reductions, involving and relating the essential characteristics of the firm. Only the most pronounced and obvious influences are included. The purpose is not to achieve complete representations of all functions, but an analysis to understand the contributions to the system behavior.

The ESAP has the following characteristics:

1. Describes cause-effect relationship for various energy types.

2. Is simple in mathematical nature.

3. Is closely synonymous to the industrial terminology.

4. Can extend to large complex situations.

5. Includes a continuous interaction of energy-related activities.

The structure contains the following essential features:

1. Customers of sever . levels of activity, DOD, IPP manufacturing units, and suppliers.

2. Flows from one level to another of information, materials, etc.

3. Decision points that control activities in the structure. These are statements of policy that determine response to conditions.

4. Information sources that connect the structure.

In this analysis, the customers (including DOD), production, suppliers, and energy sources make up the sectors, which are very similar to one another. In approaching the actual situation of energy reduction (shortage), this involves tentative identification of the pertinent variables, reducing these to equation form, and selecting the factors that are to be included.

1. A. For the Customer and DOD Sector, the quantities that are central are:

   (1) Backlog sales
   (2) Inventory

   B. Correspondingly, the major flows pertinent to the objectives are:

   (1) Orders from customers and DOD
   (2) Inventories shipped
   (3) Orders to production
   (4) Transportation to customers and DOD
   (5) Transportation from production

   C. The principal delays for these quantities and flows are:

   (1) Delay in inventories shipped
   (2) Delay in transportation to customers and DOD
   (3) Delay in backlog sales
   (4) Delay in trasnportation from production

2. A. The Production Sector involves quantities set forth as follows:

   (1) Actual raw material (RM) inventories
   (2) Unfilled purchase orders from suppliers

   B. The major flows for this sector are:

   (1) IPP production
   (2) Purchase orders to suppliers

   C. Delays in the production sector are:

   (1) Delay in purchase orders to suppliers
   (2) Delay in IPP production
   (3) Delay in transportation from suppliers

3. A. The Suppliers Sector uses quantities factors as follows:

   (1) Supplies shipped

   B. The flows are:

   (1) Supplier production
   (2) Transportation to production

   C. Delays for suppliers are:

   (1) Delay for supplier production
   (2) Delay for transportation to production.

4. A. The Energy Sector quantities include:

   (1) Energy for production
   (2) Energy for suppliers
   (3) Energy for transportation

   B. The flows that are involved are:

   (1) Energy allocation
   (2) Energy substitution

   C. The delays are:

   (1) Delay in energy allocation to industry
   (2) Delay for transportation

Changes in data, while ignoring the superimposed meaningless fluctuations, require averaging (smoothing). Averaging of data occurs to some extent at all points in the procedure. In turn, each of these same points contributes its source of fluctuations to the points or activities being controlled. The mechanism for smoothing is the numerical processing of data into averages, monthly, quarterly, and annual summaries of sales, production, and energy usages for the period specified. These formal averaging processes are found in many points and channels of the procedure.

CATEGORICAL FINDINGS

These findings are based on the ESAP of firms having IPP programs surveyed, ranging from light fabrication plants to basic production plants.

1. The critical factor causing reduced plant output is lack of materials from suppliers that are generally major users of another energy source in the production process, or lack raw materials. From the analysis, one or two suppliers from distant regions (such as northeastern U.S.) caused major reduction of output in these plants.

2. Plants have made provisions for standby energy sources for heating purposes; however, no standby is available for electrical power which is especially important to these plants since "brownouts" will cause real problems.

3. Results for the program are for a one-year period, which is valid because firms can make major changes beyond a year to cope with energy shortages.

4. IPP programs for most firms are out-of-date, as they have not been updated and reviewed periodically. Plants have added and dropped production facilities and changed technical know-how since IPP surveys were prepared.

5. Many new production facilities in the area are not involved in IPP programs.

6. Management of the firms with IPP programs feel that the Air Force/DOD lacks interest in these programs because of the poor communication with them; therefore, management does not feel any commitment to Department of the Air Force/DOD requirements, only to their regular customers.

LIMITATIONS OF ESAP

All procedures, models, systems, etc., developed to cope with a given problem or to provide information have various degrees of limitations. It is important that these limitations be recognized by the users and results interpreted with them in mind. The major limitations of the ESAP are:

1. The system developed for the project is deterministic, which does not permit the addition of data during the period.

2. Seasonal variations, cyclical changes, etc., are not included in the system. These can be added, which would make the analysis more realistic to real-world conditions.

3. There is a lack of probability distributions utilized extensively in the system. A greater use of Monte Carlo distributions would make the output closer to actual real-world events.

4. It must be recognized that data and information for the developing and testing of the procedure was limited to a small number of IPP firms located in the Midwestern Region of the United States.

5. The present United States energy program is an allocation based on past average usage rates. For example, if a firm had inefficient production equipment and/or buildings without insulation or in poor repair, the energy usage would be reduced the same percentage as the firm having highly efficient production equipment and buildings. No provisions are made in the energy program for efficient use of energy. Therefore, no methods or means are provided in the analysis for efficiency versus inefficiency of production facilities.

RECOMMENDED USES FOR THE ESAP IN AIR FORCE IPP PROGRAMS

1. Analyzing the effects of energy reduction on the firm's production capabilities.

2. Determining which production facilities in the IPP program are utilizing energy most

efficiently for selecting production facilities for IPP programs.

3. Establishing benchmarks measuring how production will be affected during energy reductions.

4. This analysis will give firms an idea of what factors will probably limit their production capabilities during various types of energy reductions. Then DOD may encourage firms either to prepare for alternative energy sources or to be dropped from the IPP program.

5. Determining what DOD supplies will be in critical shortage and should be stockpiled.

RECOMMENDATIONS FOR IMPROVING THE IPP PROGRAM

1. It has been amply demonstrated that society and industry have not yet adopted energy efficiency and conservation practices. However, the government cannot expect industry and society to practice energy conservation and reduction if it does not adopt such practices itself. The Air Force must make changes and show how these changes contribute to increased efficiency through the IPP program. The Air Force must take the leading role in this area, similar to the Space Technology program in which space technology has been adapted to commercial use.

2. The ESAP provides a range of what Air Force planners can expect from various types of energy reduction.

3. The ESAP should be performed for all Air Force IPP firms in a particular federal region to determine how energy reduction affects them. Later, the procedure would involve all federal regions having Air Force IPP plants, then still later, all DOD facilities.

4. This procedure should be employed to evaluate the effect of energy on all new proposed weapon systems. This would determine which IPP plants would be expected to experience production problems in meeting commitments.

5. Because production capabilities of IPP plants are changing through new equipment, more efficient energy utilization, new technology, raw materials, etc., the procedure should be utilized each year when Form 1519 is prepared.

6. At present, IPP plants do not have an energy priority, even during an emergency. Therefore, the Air Force and DOD should work to enact an energy priority system for IPP plants in the United States allocation program.

FUTURE SOURCES OF MILITARY JET FUELS

William L. Stanley, The Rand Corporation

INTRODUCTION

As the availability and economics of jet fuels derived from crude oil become less certain in the future, the United States Air Force will need to consider the implications of using jet fuels derived from alternative energy resources. This paper highlights some of the results of a Rand analysis for the Air Force that sought to identify (1) the most promising energy resource alternatives to crude oil for jet fuel production, (2) the most attractive military jet fuels derivable from the resource alternatives, and (3) the appropriate military R&D activities required to narrow the uncertainties associated with synthetic jet fuels.[1]

What has happened to military jet fuel prices since mid-1973 provides much of the motivation for considering alternative energy sources. The price the Air Force pays for its JP-4 jet fuel has increased by over $800 million; at present consumption rates, each penny per gallon increase in jet fuel prices translates to about a $40 million increase in annual Air Force jet fuel expenditures. Considering these increases in jet fuel costs, it seems quite possible that some time in the future, jet fuels derived from energy sources other than crude oil may become economic.

Ongoing discussions about the most appropriate future aviation fuel forms provide the motivation for evaluating more than just conventional hydrocarbon fuel types. Indeed, some have suggested that liquid hydrogen is the aviation fuel of the future, but it must be measured against the other alternatives.

The long lead times required to introduce new aviation propulsion technologies dictate that the military participate in synthetic-fuels-related research today. Our findings provide some suggestions about the appropriate research emphasis in the present environment of considerable uncertainty.

Figure 1 illustrates one of the more fundamental energy problems confronting the United States.[2] While we have a declining domestic resource base of oil and gas, we rely on imported and domestic supplies of these resources to satisfy about three-quarters of our energy needs. Fortunately, we have other resource alternatives, including abundant supplies of coal and as yet unexploited reserves of oil shale. The extent of the oil-shale resource base, and the generally favorable results of preliminary experiments conducted by the Air Force, Navy, and their contractors in the retorting and refining of oil shale to liquid

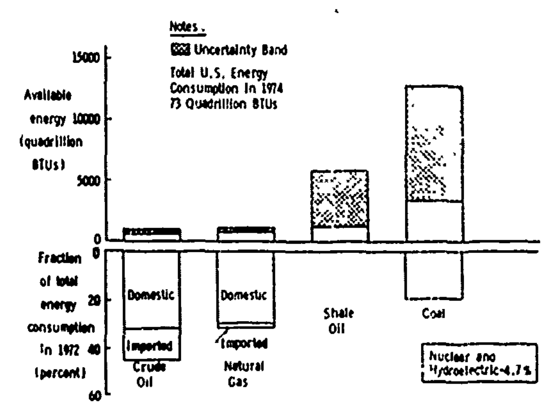

Fig. 1--U.S. Fossil Resources

SOURCES: [1][2][30][22][4].

military fuels, indicate that oil shale deserves serious consideration as a future energy source for jet fuels [23][26][14]. In this paper we consider a subject which has received somewhat less attention, the prospects for using coal as an energy source for jet fuels for Air Force aircraft entering the inventory in the 1985 to 2000 time period.

At current rates of domestic crude-oil production, we would deplete the crude-oil reserves noted in Fig. 1 in about 40 to 60 years [18], which indicates the inevitability of some shifts in our patterns of energy resource consumption to more abundant domestic supplies of energy. Of course, if and when we begin to place greater reliance on fossil resources like oil shale and coal, we will require new processes to convert these solid fuels to liquids suitable for transportation uses.

Figure 2 illustrates a respresentative, but by no means exhaustive, set of processes for producing selected jet fuels from energy resource alternatives to crude oil and natural gas. Several of the energy resources, including coal, could, in principle, be used to produce any of the jet fuels shown in Fig. 2. Oil shale could also assume such a role, although attention thus far has mainly focused on deriving liquid distillate products from oil shale. Hydrogen has the virtue of being derivable from any of the so-called renewable or ultimate energy sources (e.g., solar energy, nuclear fusion), but the economics and energy requirements of these processes do not promise to improve upon the economics of obtaining hydrogen via coal gasification in the 1985-2000 time period. Indeed, when one considers the resource base of each of the resources shown in

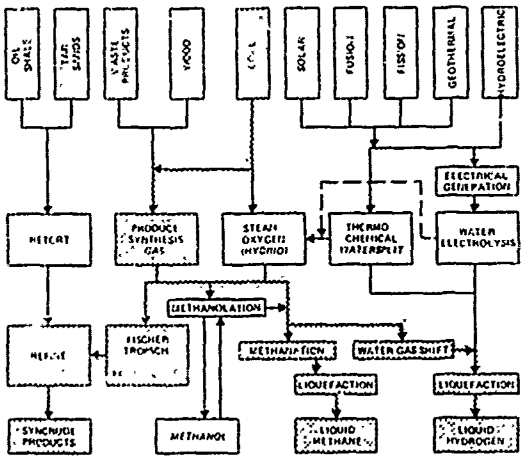

Fig. 2--Overview of Fuel Supply Processes

Fig. 2, the present and foreseeable technology for converting these resources into jet fuels of interest, and the evolving energy R&D technologies being emphasized in the United States today, one can pragmatically conclude that coal and oil shale are the most attractive resource alternatives to crude oil for jet fuel production between now and the end of the century.

COMPARISON OF ALTERNATIVES

To narrow the list of fuel candidates, we used a screening process that evaluated the difficulties in synthesizing the fuels, the comparative physical properties of the fuels in the context of aviation applications, and the performance of airplanes fueled by the various alternatives [8][17]. As a result of this exercise, we eliminated such candidates as ammonia, ethanol, methanol, etc., and concluded that two cryogenic fuels, liquid hydrogen and liquid methane, and a synthetic hydrocarbon jet fuel (or sy thetic JP, to use a common military desi .cion) held the most promise as jet fue' a ternatives derivable from coal. We then compared these three alternatives in terms of the energy requirements to produce, distribute, and store the fuels, the costs associated with such fuel supply processes, the resource requirements, and some of the environmental impacts. We highlight below some of the more relevant energy and cost aspects of that analysis.

Energy

Several factors motivated our consideration of the energy expenditures required for fuel production. An understanding of the technical reasons why certain fuel production processes require more energy than others can lead to a greater understanding of why the fuel alternatives differ in cost. It can also facilitate the assessment of the total energy-intensiveness of a given aircraft and fuel combination to aid in complying with recent DoD guidelines that require considering energy effectiveness as well as cost effectiveness in evaluating future weapon systems [16][32]. Finally, it seemed prudent to identify the total energy requirements that particular fuel alternatives would impose on the nation's energy resource base, since the Air Force must compete for these supplies with many other users in the marketplace.

To measure the energy requirements for fuel production and distribution, we developed representative fuel supply systems that use surface-mined coal from Wyoming as an energy source to produce jet fuel for a West Coast air base.[3] The numbers enclosed by dashed lines above the elements of the fuel supply systems in Fig. 3 trace the flow of resource energy (energy derived from the primary resource--coal) from extraction to ultimate distribution. Liquid hydrogen production requires 289 Btu of coal resource energy to produce 100 Btu of liquid hydrogen and 35 Btu of useful by-products. Of course, fuel production also requires other energy to fuel the diesel train, build the facilities, generate electricity for liquefaction, etc. We show this process energy below the elements of the fuel supply system. The liquid hydrogen supply system requires an extremely large process-energy expenditure to generate the electricity to liquefy the gaseous hydrogen and render it suitable for storage. In fact, the process energy required is roughly equivalent to the energy content of the gaseous hydrogen entering the liquefaction plant. As a result, about 3.2 Btu of energy must be input for every Btu of liquid hydrogen and by-products output. Thus, liquid hydrogen production uses significantly more energy than today's crude-oil supply system, which requires about 1.2 Btu of energy input for every Btu of refined products output. We shall see later how the energy-intensiveness of hydrogen liquefaction contributes significantly to the cost of liquid hydrogen.

Methane liquefaction requires only about 10 to 15 percent of the electric power required for hydrogen liquefaction [29]. Because the scale of electricity required is sufficiently low as to not preclude on-site power generation, methane liquefaction plants typically use part of the gaseous methane entering the plant to generate electricity; hence, with resource energy (the gaseous methane) supplying the energy for liquefaction, the process energy shown in Fig. 3 for methane liquefaction reflects only the energy required to build the

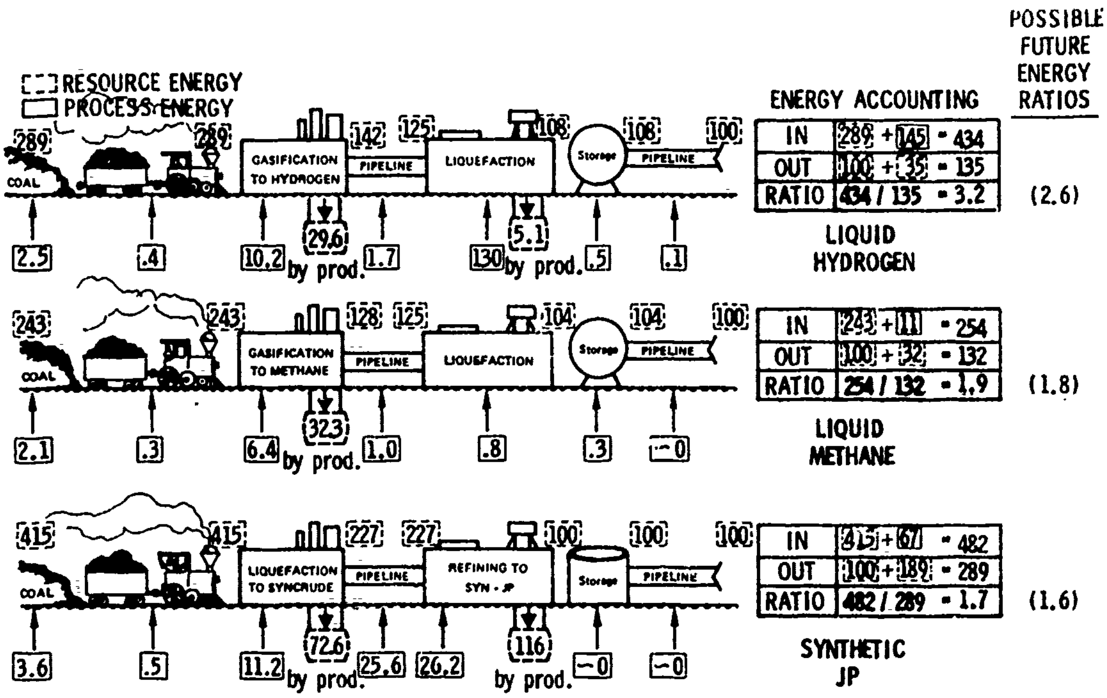

Fig. 3--Energy Needed to Produce Alternative Jet Fuels

facility [7][29][21]. The energy accounting indicates that 1.9 Btu of energy must be input for every Btu of liquid methane and by-products output.

In absolute terms, synthetic JP production requires more coal-resource energy than the other two alternatives,* not because the process is less efficient, but because the refinery processes less than one-half of every barrel of coal syncrude to a refined jet fuel; most of the remaining output is motor gasoline. Figure 3 indicates a comparatively large process-energy requirement for syncrude refining, which reflects the hydrogen treatment the coal syncrude must undergo to lower its characteristically high aromatic content, as well as some hydrocracking of heavier distillate fractions that maximizes the output of jet fuel. Reducing the yield of jet fuel would reduce energy requirements. Overall, the synthetic JP process requires that 1.7 Btu of energy be input for every Btu of synthetic JP and by-products output.

We have also made some plausible, but optimistic, estimates of possible future improvements in these fuel supply systems to arrive at the energy ratios shown on the right in Fig. 3. We deliberately assembled this rather optimistic set of estimates to test the hypothesis that the characteristically lighter liquid-hydrogen-fueled aircraft might use less total energy than the other alternatives. The results indicated that for a broad class of military missions, the large energy expenditures associated with liquid hydrogen production and distribution more than offset the lower on-board energy consumption of a subsonic liquid-hydrogen-transport aircraft [17]. In an energy context, the synthetic-JP-fueled aircraft proved more energy effective than the other two alternatives for almost all the missions considered.[5] We can conclude from this energy assessment that compared to the crude oil supply system, the synthetic JP alternative does not represent a means to save energy, although it does represent a possible means to save crude oil by using an alternative energy resource.

Costs

Any absolute economic assessment of alternative jet fuel costs must remain somewhat speculative until operating experience is accumulated with large synthetic fuel demonstration plants. At this writing, any such plants would appear to be at least three to five years away from operation. Nonetheless, by making consistent assumptions about the supply systems of the three fuel alternatives, we can

gain some insights about the relative costs of producing and delivering the fuels. While we originally expressed the cost analysis on a 1974 dollar basis, we will translate the more relevant results to a 1978 dollar basis at the conclusion of the assessment.

We developed average fuel costs for the production and delivery of the fuels to a group of air bases, assuming a mix of underground-mined coal from the east and surface-mined coal from the west having an average price of about $9.64 per ton, or 54¢ per million Btu. Table 1 indicates the capital cost of the energy-conversion facilities per daily million Btu of fuel products, including a 28 percent "ownership" cost over and above the basic plant investment to cover interest during construction, working capital, start-up capital, etc. Because of the capital-intensiveness of these facilities, the method of financing has a strong influence on fuel costs.

Table 1

CAPITAL COSTS

Energy Conversion Facility	Capital Cost per Daily Million Btu of Fuel Products (1974 $/$10^6$ Btu)
Coal liquefaction	1690
Syncrude refinery	490
Coal gasification to hydrogen	2590
Hydrogen liquefaction	2520
Coal gasification to methane	1730
Methane liquefaction	340

Figure 4 identifies the major cost categories for energy conversion, including the fixed (capital charges), operating (recurring labor costs, property taxes, raw materials, etc.), and energy costs. Note the large contribution of liquefaction electricity to liquid hydrogen costs. If we apply credits for the by-products, particularly the large gasoline by-product credit, we obtain costs of $8.20, $3.56, and $2.91 per million Btu for the liquid hydrogen, liquid methane, and synthetic JP, respectively. These costs assume industrial financing that yields a 10 percent discounted cash flow return-on-investment after taxes. Some have suggested that investors may very well demand returns of 15 percent or more because of the risks involved, and as a means to generate the equity for the rapid build-up of a synthetic fuels industry [25]. As a consequence, fuel costs could very well reach or exceed the values shown in the box in Fig. 4. We can conclude from this assessment that in a relative sense, synthetic JP would cost significantly less than liquid hydrogen, and modestly less than liquid methane. The fuel cost sensitivities to resource costs, financing assumptions, and plant costs shown in Figs. 5 and 6 also indicate that liquid hydrogen costs are generally more sensitive to unfavorable changes in the parameters because of the less-efficient production and distribution system.

The dramatic differences in peacetime and wartime jet fuel demands by the military (e.g., consumption changes of 100 to 300 percent) could also pose a serious problem for the particularly capital-intensive hydrogen liquefaction process. Unless a large market of interruptible users could be developed to use the excess liquid hydrogen plant capacity during peacetime, the liquefaction facility owner would have to raise fuel prices appreciably to cover his large fixed costs. In other words, there could be a large cost penalty for underutilizing the system [8]. The synthetic JP option has the apparent advantage of having a refinery product slate more amenable to assimilation into existing petroleum markets during peacetime.

A mission analysis of airplanes fueled by these three alternatives indicated that for a broad class of present and future mission applications, the synthetic-JP-fueled aircraft proved significantly more cost effective than the other alternatives, for fuel costs in the range of those cited in Fig. 4 [17]. It would seem that only major reductions in the costs of liquefying gaseous hydrogen would improve the relative attractiveness of liquid hydrogen airplanes.

Moving from relative comparisons of the fuel alternatives to absolute comparisons with present petroleum market conditions entails considerable uncertainty, but nonetheless we will do so to illustrate the presently unfavorable economics of the synthetic JP alternative. Depending on the financing, the synthetic JP cost in our example ranges from 37¢ to 45¢ per gallon in 1974 terms, or converting to 1978 terms, about 45¢ to 58¢ per gallon [6][5]. As indicated in Fig. 4, as of October 1977, the Air Force was paying the Defense Fuel Supply Center 42¢ per gallon for its JP-4 fuel, considerably less than the cost of a synthetic JP fuel [3]. Other analyses using alternative assumptions about coal conversion technology, coal costs, and financing yield a generally broad range of synthetic JP cost estimates, but virtually all of these analyses indicate that synthetic JP from coal would not be competitive under present market

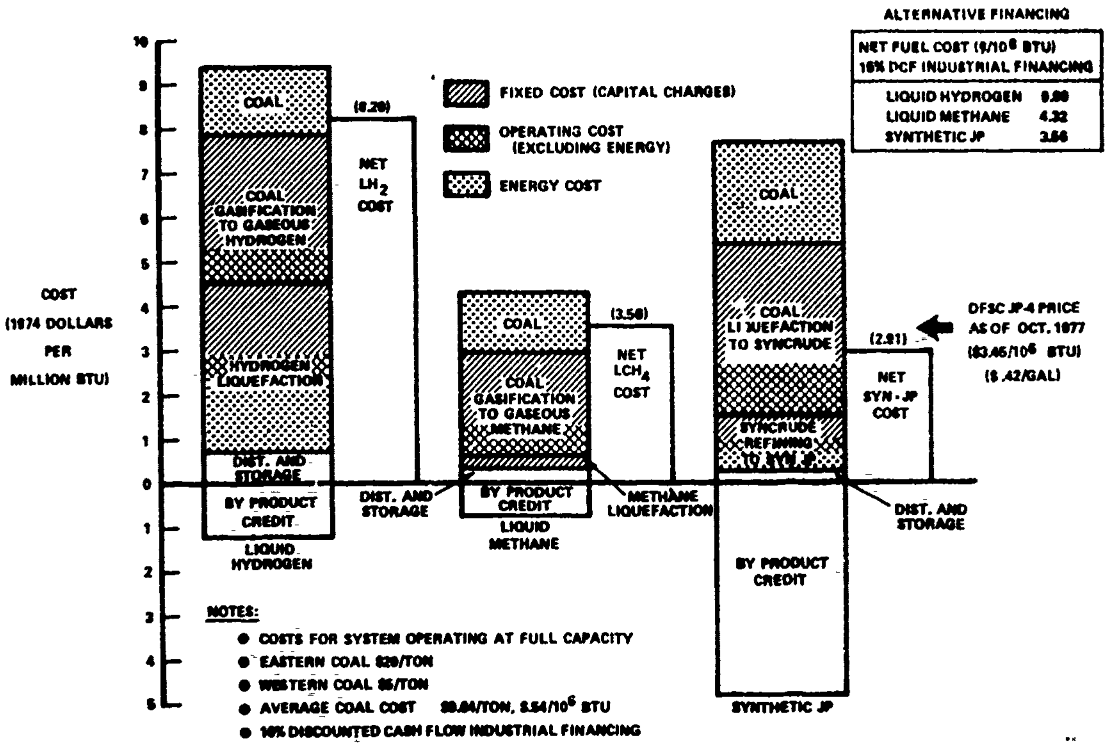

Fig. 4--Jet Fuel Costs

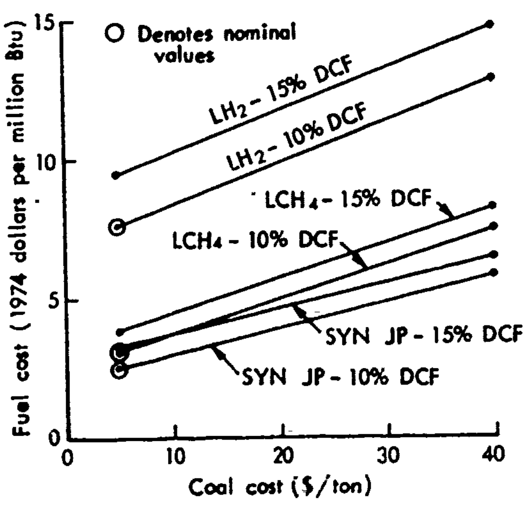

Fig. 5--Sensitivity to Coal Cost and Financing Method

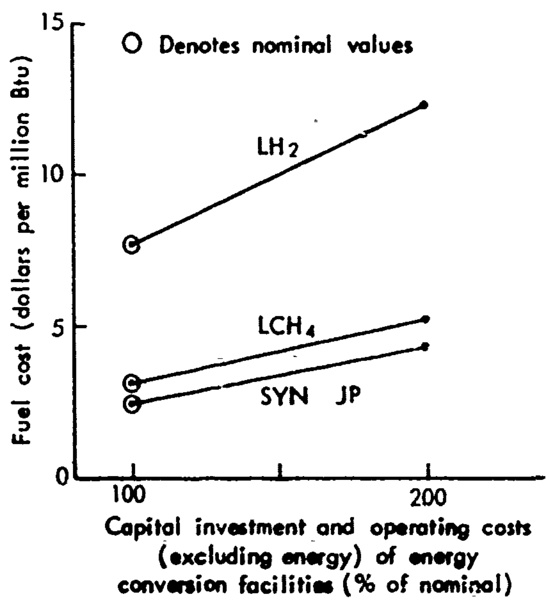

Fig. 6--Sensitivity to Facility Costs

conditions [24]. The risks posed by these unfavorable economics, as well as the uncertain pricing basis of world oil, have tended to inhibit private industry from aggressively pursuing the synthetic fuel option without government assistance of some form.

RESEARCH AND DEVELOPMENT EMPHASIS

While the present world oil price does not make synthetic JP an attractive alternative in today's environment, the long lead times needed to introduce new propulsion technologies more or less require that the military participate in synthetic-fuels-related research today in order to be in a position to choose the most cost-effective synthetic JP fuel option at some future date. For the military aircraft user and developer, the primary issue concerns defining the proper technical and economic tradeoffs between engine technology and fuel processing at the refinery.

Coal-derived fuels have characteristics that can cause problems in jet engines. Their generally high aromatic content, or conversely, low hydrogen content, substantially contributes to combustion problems. Coal-derived fuels generally have higher freezing points, and when burned in jet engines, generate more smoke and increase combustor liner temperatures and infrared signatures. They have poorer thermal stability properties than petroleum fuels and pose some compatibility problems with elastomeric seals. But research already under way has demonstrated that improvements in combustor and fuel system technology can help deal with many of these problems [13]. On the other hand, at some additional cost in energy and dollars, refiners can hydrotreat coal liquids to reduce their aromatic content. Tradeoff opportunities also exist to deal with the characteristically high nitrogen content of shale liquids [14]. But the refinery-engine tradeoff interface has not yet been defined to a level of precision that could support major development decisions.

Indeed, the considerable uncertainties about synthetic JP fuel supply and utilization systems argue for a cautious and flexible R&D approach by the military. The pace and extent of oil shale and coal resource development remain uncertain. The identification of the preferred fuel-conversion technologies and their economics have yet to be defined. We still have much to learn about the effects of synthetic JP fuels on aircraft engines and fuel systems. Specifications for future jet fuels are still being discussed and debated.

The uncertainties seem to dictate a parametric approach to define fuel characteristics and the associated refinery process requirements. In other words, an R&D program structured to gain information about the spectrum of possible outcomes that might result from the present uncertain energy situation seems preferable to making an early commitment for a particular resource and fuel type. Such an R&D approach should place the military in a good position to exercise the synthetic JP fuel option when these fuels enter the marketplace as alternatives to petroleum fuels.

FOOTNOTES

[1]This paper has been prepared for presentation at the Seventh Annual DoD Procurement/Acquisition Research Symposium, May 31-June 2, 1978, at Hershey, Pennsylvania. The views expressed in this paper are the author's own and are not necessarily shared by The Rand Corporation or its research sponsors. The paper is based on research fully reported in [8] and [17].

[2]Crude oil and natural gas estimates include identified resources and estimated undiscovered resources recoverable with current technology (unshaded area). The shaded area refers to additional resources that might be recovered with enhanced recovery techniques. The oil-shale estimate (unshaded) includes 25 to 100 gallon per ton identified recoverable deposits in the Green River Formation. The shaded area indicates potentially recoverable 10 to 25 gallon per ton deposits in the same formation, which would require development of new recovery techniques. The lowest coal estimate includes recoverable measured and indicated resources. The highest coal estimate includes recoverable measured, indicated, inferred, and hypothetical resources.

[3]We used a variety of sources to assemble the operating characteristics and costs for the elements of the energy distribution and conversion systems [15][19][20][9][27][12][10][21][31][11][28][7].

[4]Observe, however, that if coal is used to generate the electricity for hydrogen liquefaction, the liquid hydrogen supply process requires about as much coal as the synthetic JP alternative while delivering about half as much energy.

[5]Our energy and cost analyses did not consider hypersonic aircraft applications in which the cryogenic properties of hydrogen or methane fuels might facilitate innovative aircraft design concepts.

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NEGOTIATED PROCUREMENT, SMALL BUSINESS,

AND CONTRACT MANAGEMENT

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AN ANALYSIS OF THE NEGOTIATED COMPONENT OF FEDERAL PROCUREMENT

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IMPORTANCE OF THIS RESEARCH

Abnormal conditions or forces sometime preclude the setting of the price of particular goods or services through normal operation of the economic marketplace. This situation is known as a "market failure." If the government intercedes and establishes regulatory policy to correct such market failure, then the affected part of the economic system becomes part of the "regulated" sector. Federal government purchases in which price cannot be determined independently by competitive forces in the marketplace are classified as "negotiated procurements." Thus, such negotiated procurements can be regarded as composing a regulated sector of the economy. A better understanding of the nature of this regulated sector is required in order to allow proper formulation/modification of policy governing these procurements.

This paper will reflect findings from research on the composition of the negotiated component of total Federal procurement expenditures.

CONTENT OF PROPOSED RESEARCH PAPER

This proposed paper will document research findings related to analysis of Federal negotiated procurement. Research findings to be incorporated will attempt to answer the following questions:

a. What is the composition of total Federal negotiated procurement stratified into the following categories:

(1) Small Business Set-asides.

(2) Labor Surplus Set-asides.

(3) Competitive Negotiated.

(4) Sole Source - Standard Goods.

(5) Sole Source - Non-standard Goods.

(6) Small purchase ($10K or below).

b. What is the composition of total Federal negotiated procurement in terms of classes of goods involved, stratified by such categories as:

(1) SIC codes.

(2) Major systems.

(3) Standard Goods.

(4) Service type performance (such as A&E services).

c. Does the supply side responding to the Federal negotiated procurement demand show any special trends or concentrations, such as:

(1) Dominance by individual firms, or groups of firms.

(2) Correlation with SIC industrial sectors.

d. What patterns are apparent from a cross-sectional analysis by Federal agencies for the above stratifications?

BACKGROUND

Total Federal procurement expenditures currently approximate $50B annually. In FY-76, the amount was $54B, of which $46B was classified as "negotiated." The Department of Defense accounts for approximately 75% of negotiated expenditures, but other agencies also expend significant amounts using the negotiated procurement method.

A METHOD OF ASSESSING THE TECHNICAL AND INNOVATIVE CAPABILITIES OF SMALL BUSINESSES*

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ABSTRACT

This study proposes a comprehensive set of indicators whose purpose is to measure selected dimensions of the research, development, and innovative capabilities of small businesses. Over 70 indicators are suggested, grouped in four categories: 1) resources, 2) structure and organization, 3) administrative and legal aspects and 4) outputs. These indicators resulted from an extensive survey of the literature and the authors' experience extending over a period of 25 years in the field of R&D/Innovation management. Although many measurement problems still remain unsolved, this study is a preliminary attempt to gather and to form a unified body of indicators of small business R&D capabilities, until now scattered through different sources. The potential set of indicators emphasizes many specific capabilities that are required or desired by federal agencies as part of their RDT&E procurement process.

INTRODUCTION

There has always been high interest in the role of small business in the U.S. economy and society as an essential element in the health and growth of the country. This interest has been manifested by the history of legislation favoring or protecting small businesses and the financial institutions that serve them, such as the Small Business Investment Companies which Congress mandated almost two decades ago.

In addition to their general role in providing employment, diversity, income and stability to the economies of various states and regions, small businesses are also viewed as a source of entrepreneurial energy, ideas, new products, risk-taking, and managerial talent, and expression of many of the kinds of qualities that have built this country. Traditionally, many small businesses - some as small as an individual inventor and his assistant (frequently his wife or other members of his family) - have provided new products, processes, services, methods of merchandising, and other innovative approaches to business. Many of the devices and systems in common use originated from individual inventors or small firms which either employed inventors or were formed to exploit inventions.

In the current era of large-scale R&D (Research and Development) which is dominated, at least quantitatively, by giant firms, the role of small firms in the overall R&D/Innovation process has been questioned in terms of potentially unused or unexploited R&D capability. There has been, for some time, a feeling among some observers that small firms do not get their "fair share" of government R&D contracts and grants. This concern is reflected in the "set aside" provisions which are part of the authorization acts and regulations of a number of federal agencies. Another side of the issue, however, is the belief that there is a significant reservoir of unused or unrecognized R&D and related technical skills and capabilities among the small firms of this country.

The purpose of this paper is to propose a candidate set of factors and indicators which may be used to assess the R&D and technical capabilities of small firms. They will have to be subjected to thorough pilot testing before they can serve on a routine basis.

DEFINITION OF RESEARCH AND DEVELOPMENT

This issue poses a major dilemma in the specific case of small businesses. In its annual surveys of industrial R&D, the National Science Foundation has used, over many years, the following definition of R&D (1):

> Research and development includes basic and applied research in the sciences and in engineering, and design and development of prototypes and processes ...... it includes such activities whether assigned to separate research

*This study was supported by the National Science Foundation, Purchase Order No. 77-SP-0999 to International Applied Science and Technology Associates (IASTA, Inc.).

and development organizational units of the company or carried on by company laboratories and technical groups not part of a research and development organization.

This definition has been accepted fairly generally as a useful definition of R&D which allows for feasible identification and measurement. We have commented elsewhere (2) on the limitations which this definition imposes on our ability to fully assess the total R&D/Innovation capacity of the U.S. and other countries or even the full R&D capabilities of firms, parts of which are not included in the activities delimited as "R&D." That issue remains as a limitation on any survey data for the <u>entire</u> R&D capability of the industrial sector, but it is of vital importance to any assessment of the total R&D/Innovation capability of the <u>small business</u> sub-sector of the industrial sector.

R&D IN THE SMALL FIRM

R&D and related activities in large and very large firms, as well as many medium-size ones, are typically organized into formal departments with budgets, staffs, and names such as: corporate research, divisional engineering, product development, R&D, advanced development, product engineering, process engineering, process development, divisional laboratory, central laboratory, quality assurance, market research, tool engineering, process control, customer service, etc., etc. These formal activities are fairly easy to identify in terms of size (number of people and/or budget), location, assigned duties or objectives, facilities, and other formal characteristics. This enables them to be included or excluded from the periodic surveys conducted by NSF and others (e.g., several trade publications and research institutes which also make periodic R&D surveys).

In the case of small and very small businesses, however, the identification and measurement of R&D capability is typically a very different matter. Few small businesses have formal departments for all of the technical functions they actually perform as part of the R&D/Innovation process or even the R&D part of that process. Many of them do not have <u>any</u> formally-designated departments or laboratories with exclusive missions as defined by the titles of larger-company activities. In the extreme, the lone technical entrepreneur performs all or many of these functions himself, sometimes with the aid of an "assistant" or with occasional help from outside consultants and service organizations.

For larger small businesses, with some more structure and technical capability, the production or marketing people, or a general purpose "chief engineer" (with or without assistants) often performs the whole spectrum of R&D/Innovation activities in a relatively undifferentiated manner. This undifferentiated manner can be described as "doing what is necessary and feasible to get the product out the door, keep the factory running, keep the customers happy, or keep the regulators off our back."

For many small businesses, a major share of the so-called R&D is done for them by customers, suppliers, competitors, or people who sell know-how and technical information. There is still, however, a need for application of the knowledge attained from outside and adaptation of the product, process, materials, or service to the particular conditions of the firm.

ASSESSING THE R&D/TECHNICAL CAPABILITIES OF SMALL BUSINESSES

The factors and indicators suggested by our study are considered important for the conduct of R&D-related activities in the small firm and cover many aspects of such activities.

The 19 factors are organized in 4 categories or groups, and over 70 illustrative indicators are proposed as potential measures of the factors.

DEFINITION OF THE GROUPS

Group I - <u>Resources-Inputs</u>: refers to the existence of human, financial, administrative and facilities resources in the small business related to R&D activities.

Group II- <u>Structure and Organization</u>: refers to selected characteristics of small firms, their R&D activities and attributes of the type, volume, sources and performance of such activities.

Group III- <u>Administrative and Legal Aspects</u>. refers to the extent of administrative capabilities needed to perform contracted R&D, and the legal problems affecting R&D potential of the small firms.

Group IV- <u>Outputs</u>: refers to the types, quality, and reliability of technical outputs produced by the small firm.

A summary of the factors and their illustrative indicators is given in Figure 1 below,

CONCLUSIONS

The factors and indicators for assessing the R&D/Innovation capabilities of the small firm represent an extensive list which may be used by small businessmen and R&D grantors as a general reference in the analysis of such capabilities. Severe methodological problems still remain in terms of data collection and analysis of many indicators. This study was, however, a first attempt at organizing a possible set of factors for uncovering the hidden R&D/Innovation potential of small businesses.

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FIGURE 1

SUMMARY OF FACTORS AND ILLUSTRATIVE INDICATORS

GROUP I: RESOURCES - INPUTS

Factors:	Illustrative Indicators:
1. Human Resources	1.1 Number of scientists and engineers (FTE) 1.2 Number of technicians involved in R&D (FTE) 1.3 Distribution of professional specialists/disciplines 1.4 Distribution of technical skills of technicians 1.5 Average experience (years) of key technical personnel
2. Stability of Personnel	2.1 Rate of turnover of key technical personnel 2.2 Average starting salary of key technical personnel 2.3 Sources of recruitment of key technical personnel
3. Marketing Sophistication	3.1 Awareness of government bid procedures 3.2 Awareness of specific RFPs 3.3 Number of government bids made per time period 3.4 Number of complaints filed by small business with SBA and other government agencies (related to SB's inability to compete for bids)
5. Financial Resources and Financial Stability	5.1 Expenditures for R&D 5.2 Financial ratios 5.2.1 R&D expenditures per net sales 5.2.2 Leverage ratios 5.2.3 R&D expenditures per operating costs 5.2.4 R&D expenditures per scientist/engineer 5.3 Distribution of sources of R&D funds (government, industry, company) - qualitative 5.4 Expenditures for R&D by source of funds
6. Facilities and Equipment	6.1 Expenditures for technical equipment and instruments 6.2 Rate of replacement of technical equipment and instrumentation 6.3 Distribution of means of obtaining equipment and instruments by source of funds (e.g., loans, rental, purchase with company funds)

GROUP I: RESOURCES - INPUTS (continued)

Factors	Illustrative Indicators
	3.5 Number of RFPs reviewed by small firms per time period
	3.6 Number of advertisements in trade magazines
	3.7 Participation in trade shows
4. Technical Information	4.1 Types and number of technical publications to which the small firm subscribes
	4.2 Number of requests for technical information made by firm's technical personnel to information sources
	6.4 Distribution of equipment and facilities by categories (e.g., physical space, computational facilities, security controls)

GROUP II: STRUCTURE AND ORGANIZATION

Factors:	Illustrative Indicators:
1. Firm and Industry Structure	1.1 Size of firm (by number of employees and net sales)
	1.2 Geographical location of firm
	1.3 Years in business
	1.4 Type of organization (e.g., partnership, sole proprietorship, corporation)
	1.5 Major markets served (e.g., consumer/industrial/government) by sales
	1.6 Major activities/product lines (e.g., product/service)
	1.7 Proximity to research labs/universities/ major industrial complexes
	1.8 Product differentiation: number of different products/services of the firm
2. Dependence on Major Industries	2.1 Concentration of sales to single client
	2.2 Concentration of R&D effort performed for single client
	2.3 Concentration of resources acquisitions from single supplier
3. R&D Activities	3.1 Types of R&D performed (e.g., research, development, testing)
	3.2 Expenditures by type of R&D performed
	3.3 Ratio of R&D in-house/contracted to outside entities
	3.4 Distribution of organizations to which the firms contract R&D, by sector and size
	3.5 Number of joint ventures with other small firms to perform R&D/by source of procurement (government, industry)

Factors:	Illustrative Indicators:
4. Technical and R&D Tradition	4.1 Number of years of R&D performance
	4.2 Average dollar size of prime R&D contracts, by contracting agency or company
	4.3 Use of outside sources (universities, R&D labs, consultants) in the performance of R&D activities
	4.4 Number of unsolicited proposals put out by firm for R&D procurement
5. Uncertainty/Risk of R&D Activities	5.1 Percentage of projects/bids rejected by firm due to risk content, by type of R&D (refers to bids the firm was aware of and able to undertake)
	5.2 Percentage of companies which do not bid for R&D projects due to risk factors (refers to companies who might have R&D capabilities)
6. Performance on Contracts	6.1 Percentage of R&D contracts with on-time performance
	6.2 Percentage of R&D contracts with on-budget performance
	6.3 Percentage of R&D contracts with on-specifications performance
7. Degree of Competition	7.1 Share of market
	7.2 Average number of firms bidding for government contracts with same major product/service/skills

GROUP III: ADMINISTRATIVE AND LEGAL ASPECTS

Factors:	Illustrative Indicators:
1. Proprietary Rights	1.1 Percentage of government R&D bids rejected due to problems with proprietary rights 1.2 Awareness of legal aspects of government R&D procurement 1.3 Use of legal assistance in contacts with government procurement agencies and industrial firms
2. Administrative Capabilities	2.1 Percentage of firms which have formal accounting and reporting personnel 2.2 Percentage of firms which have security clearance for government contracts

GROUP IV: OUTPUTS

Factors:	Illustrative Indicators:
1. Quality and Reliability of Outputs	1.1 Expenditures for quality control, by product line 1.2 Company's reputation for making adjustments 1.3 Records of unsatisfactory materials, including returns
2. Types of Outputs	2.1 Distribution of R&D outputs (e.g., tests, product improvement) 2.2 Number of patents produced 2.3 Number of innovations produced 2.4 Number of scientific and technical publications by key technical personnel 2.5 Number of new products developed by the firm
3. Outputs Benefits/ Contributions	3.1 Types and percentage of R&D outputs used internally in the firm 3.2 Income to firm from patents 3.3 Income to firm from sale of R&D related products and services
4. Clients	4.1 Distribution of firm's R&D clients 4.2 Opinions of firm management and key technical people on potential R&D clients 4.3 Opinions of selected clients on contribution to them from R&D outputs of small firm

BARRIERS TO EFFECTIVE COMMUNICATION IN AFSC SUBCONTRACT MANAGEMENT

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Introduction

Surveillance of the prime contractor's subcontract activities has been a problem for the Air Force and Department of Defense since prime/subcontractor arrangements have been in existence. Some authorities believe this problem stems from the privity of contracts principle, which prohibits the government from directly interacting with the subcontractor. Others believe it has been our direct engagement with the subcontractor which has caused many of the problems we face today. Whatever the reason, today's system program director (SPD) faces the challenge of performing surveillance over critical subcontracts and components to prevent or curtail problems which lead to cost and schedule growth on the program. The systems program office (SPO), contract administration services (CAS), and industry must exercise subcontract management (SM) efficiently to insure that the large number of program dollars flowing to the subcontractors is used to the maximum to support weapon systems development.

Problem

Primarily through the effort of Hq AF Contract Management Division (AFCMD), extensive progress has been made in the effectiveness of Air Force Systems Command (AFSC) subcontract management. This is especially true of cost-reimbursement and incentive contracts during the Demonstration/Validation and Full-Scale Engineering Development phases of the weapon systems acquisition process. However, recent individual and team studies indicate that AFSC elements still have significant difficulty in communicating their need for subcontract management support. After five years of concentrated effort within AFSC, the key organizations of effective AFSC SM surveillance, the SPO and Air Force Plant Representative Office (AFPRO), are still not operating on the same frequency. However, the communication gap is not restricted to these organizations, but is Command-wide.

Objective

The objective of the study is to identify communication barriers in the subcontract management area within all of AFSC and focus on several issues which presently inhibit good communication. The underlying reason for choosing this objective is to enhance the effectiveness of the AFSC SM process and therefore provide the most cost-effective support for our developing programs.

Study Hypotheses

The following three hypotheses will be used to test the validity of the problem statement. The findings and conclusions of each hypotheses will result in the retention or rejection of an hypothesis. Hypotheses which are retained will substantiate the existence of the proposed problem statement.

1. There exist varying perceptions by the SPO and AFPRO concerning what should be emphasized in the area of subcontract management and how it should accomplished. This condition has led to a gradual erosion of direct program support in the subcontract management area.

2. There is within the Command a poor understanding by the program offices of what SM support should be provided by the AFPRO during the contract administration portion of the weapon systems acquisition process.

3. There has been a loss of subcontract management corporate memory throughout the Command. Accordingly, we are not maximizing our past SM experiences.

Review

As a result of an AFSC subcontract management study in 1972, the Command began to actively pursue visibility into subcontract operations. Hq AFSC issued policy guidance which directed greater involvement by the buying organizations and plant representative offices in subcontracting operations. After several years of deliberations and discussions with DOD and the Armed Services Procurement Regulation Committee, AFSC published revised guidance as an AFSC Supplement to ASPR 23-5000, titled Subcontract Management, AFSC ASPR Supp 23-5000, dated 7 August 1975, set forth the policy for AFSC program office surveillance of a prime contractor's subcontract management system. Also, 23-5000 established the requirement for prime contractors

to submit a subcontract management plan in response to requests for proposal for all major acquisition systems. At a minimum the SM plan would include a list of critical subcontracted items, reference to a proposed make or buy plan, a description of the procurement planning policies, and a description of the program management organization which would implement and maintain surveillance over critical subcontracts.

With the advent of the new AFSC supplement, the AF became drawn into (or drew itself into) the subcontracting arena. Now, the prime contractor was contractually bound to provide the contracting officer into the subcontract management process. As a result, the contractual authority for the AF was to become more aware, and active if necessary, in this process. At the same time, the subcontract management plan and subcontract management clauses served to notify the contractor that the AF was becoming very serious about insuring that contractors are controlling subcontract costs on major programs.

An outgrowth of the AFSC interest in this area was a study conducted by AFCMD to determine how the Command could improve subcontract surveillance. AFCMD would also assess the extend of and exercise influence over subcontract and overhead costs in the development of weapon systems. The study resulted in development of the following changes:

1. A Directorate of Subcontract Management at Hq AFCMD was established to centralize all tasks related to subcontract management. Similar organizations were established at the AFPROs with the necessary organizational structure, resources, and expertise to apply, when necessary, the "clout" to the prime contractor, in the management of his subcontractors. The AFPRO/SM Division was to be responsible for assuring that t' contractor complies with public . .w, prime contract terms, and sound business practices. To this end, the AFPRO/SM Division would use a formalized systems approach to management in the subcontract area. (1:30)

Up to that point, the entire SM approach was geared toward getting a systems evaluation function established and operating. There was little emphasis on providing direct support or assistance for individual subcontracts in support of the program office. The reasoning apparently was to develop a preventive approach (versus reactive) to solving subcontract management problems in the prime's procurement system. The problems of the individual subcontracts would be left to the ACO and the program office to resolve.

With the establishment of the new AFCMD organization and the publication of the AFSC ASPR Supplement for subcontract management, the AF began to penetrate the prime's subcontract surveillance process. Government officials would now be more aware of the prime's actions with his subcontractors and would continually review the prime's procurement system.

During 1976, several independent studies were conducted in the contract administration area which took a hard look at SM. The first was the DOD study, <u>Project FORWARD LOOK</u>, which attempted to forecast operation and resource requirements needed to accomplish the CAS mission in the face of an ever-changing procurement environment and declining resources. The principle objective of the study was to develop improved contract administration procedures that would optimize manpower resources for performing essential CAS tasks.

Since subcontract management portions of the CAS functional disciplines were not separated in the user satisfaction survey from the actions paramount to the prime contractor, it is difficult to draw positive conclusions about SM surveillance. However, the report showed a substantial difference in the level of satisfaction between the various functional areas which affect subcontracts. Also reflected in the survey was a higher degree of satisfaction in the area of systems review than in the area of direct support to the program offices.

A second study was conducted by AFCMD, titled <u>Prioritization of Contract Management Tasks</u>. The objective of the study was primarily to assist AFCMD managers at all levels in prioritizing their work and allocating Command resources. The SM results of the study were as follows:

1. There was substantial disagreement between the AFPROs and AFCMD on what should be emphasized in SM.

2. In all cases except SM, there was significant agreement on the priority of the AFPRO tasks between the AFPROs and the SPOs. In the SM area many specifics were cited, but in

general, disagreements stemmed from differences in perspective. At the direction of Hq AFCMD, the AFPRO/SM divisions employ a "systems-oriented" management concept while the SPOs are more "operations-oriented." SPOs are more interested in the tasks that concern direct support to the program office. (2:86-7)

In all, the AFCMD study presented a rather unfavorable picture concerning the health of subcontract management, both within AFCMD and between AFCMD and the product divisions.

At the direction of the Commander, AFSC, a third major study was conducted in 1976 by the AFSC Program Management Assistance Group (PMAG) to find ways to improve SPO/AFPRO teamwork effectiveness in AFSC system acquisition. The PMAG concluded that the AFSC, as a whole, and Acquisition (Product) divisions in particular, have a tendancy to regard the Contract Management Division as a separate culture from Systems Acquisition. This separate culture point of view has resulted in educational and training deficiencies for both SPO and AFPRO personnel which, in turn, have resulted in an educational and experience gap. This situation has had a major impact on SPO/AFPRO communication, perception, and teamwork. (3:37)

Of interest to this study are the four recommendations which addressed AF subcontract management functions: (1) issue policy letter to require subcontract management in Memorandums of Agreement (MOAs); (2) apply resources and emphasis early during consent decision phase of prime's development of subcontract structure; (3) develop better liaison with secondary CAS organizations; and, (4) issue a policy letter requiring SPOs to establish or designate a focal point within the SPO for subcontract management. (3:31)

The four SM recommendations, while only discussing a few of the existing problems, did generate further AFSC Command awareness of the breadth of SM communication problems. These were problems which ultimately affected the surveillance phase of RDT&E contracts for multi-million dollar procurements.

The year 1976 was a banner year for DOD and AF "reviews" in the contract management area and more particularly the area of subcontracts. However, recommendations for improved communication were few, and actions even fewer.

Before discussion of the changes which are occurring, we need to understand how AFCMD accomplishes the subcontract management task today through the Contractor Management System Evaluation Program (CMSEP). This program is the core management tool for all of AFCMD operations. The SM portion of the program provides the AF the ability to continually evaluate the contractor's management of his procurement process from the receipt of the request for proposal for the prime contract all the way through to the closeout of the subcontracts. The AFPRO/SM staff conducts periodic reviews of key elements of the contractor's procurement system throughout the year. These periodic reviews form the basis for recommending approval or withholding approval of the procurement system by the Principal Administrative Contracting Officer. When deficiencies are found in the procurement system, they are reported to the Air Force Plant Representative (AFPR), who reports the findings to the company chief operating official, the affected SPO director, and AFCMD. The notification puts the contractor into action to correct the problem and lets the SPO director know there is a problem at his plant. Considerable emphasis is placed on correcting deficiencies which could lead to management problems and increased program costs.

Support for the CMSE Program has varied widely throughout the Command. In the last few years, AFSC has supported the program and encouraged acceptance and use of CMSEP reports by the SPOs. However, acceptance of the program by the product divisions has been slow to develop and in many cases CMSEP has caused significant animosity at the working level. Next we will discuss these varying opinions.

<u>Hypothesis 1</u>

The AFCMD/SM Division was established to place greater emphasis on subcontract management and reduce deficiencies in the prime contractor's procurement system, before these deficiencies could lead to individual subcontract problems. Unfortunately, this was not the approach which the system program offices had hoped the new organization would take. The SPOs were looking for greater visibility into their subcontracts and greater support for the program office from the AFPRO/SM divisions. Hq AFCMD had directed the AFPROs to follow a contractor systems-oriented approach of subcontract management. Individual subcontract

problems continued to be addressed by the SPO in concert with the ACO and Defense Contracts Administration Service (DCAS) elements in or near the subcontractor's plant. Also, many major program offices viewed subcontract management during this time as an exercise in crisis management. Although many of the AFPRO members in SM saw clear advantages in assisting the SPO with its subcontractor problems, they were bound by AFCMD to emphasize systems management. Hence in 1974-1975, the AFPROs were literally caught in the middle of a struggle between AFCMD and the product divisions, while simultaneously attempting to serve both masters. The communication barriers in SM between AFCMD organizations and the product divisions were at their apex. There was an almost total lack of understanding between the parties as to what the other was attempting to do in SM. Also, MOAs for the most part were silent concerning SM support. This situation was especially difficult for the product divisions to accept since by its very existence, an AFPRO is a service organization, dedicated to support the new AF development program. Yet AFPRO/SM divisions were doing what their headquarters desired at the expense of providing direct service to the SPO.

Between 1975 and 1977 a dichotomy affecting SM appeared within the Command. On the one hand we saw more involvement in subcontract activities by the SPO and the contracting officer as directed by AFSC ASPR Supp. 23-5000. On the other hand we saw less involvement by the AFPROs as directed by AFCMD Regulation 70-24, Subcontract Management Program. Although not formally recognized in AFSC, this dichotomy has been a root cause in fragmenting the total team concept for SM.

With the publication of the AFCMD Prioritization of Contract Management Tasks study in June 1976, the real SM problems within AFSC came to light. Given the opportunity to state their opinions and concerns, the AFPROs and SPOs clearly showed that AFCMD/SM and the product divisions maintained a divergent perspective from that of AFCMD concerning what should be done. The SPOs would have to reorient their thinking and accept the AFCMD systems approach to subcontract management. Accordingly, the communication problems and lack of understanding in SM remained. At this point in mid-1976, we saw the communication barriers solidly entrenched.

We will now look at what appears to be a changing emphasis within AFCMD subcontract management. AFCMD appears to be drifting from its former staunch approach of accomplishing nothing but systems evaluation to one of performing systems evaluation and accommodating program office needs. This charge has resulted in a strengthening of SM relationships between AFCMD and the product divisions. Let us now examine the evolution of this shift in emphasis by reviewing some of the policy changes which occurred in 1976-1977 and the reasons for the changes.

As a result of AFCMDR 70-24 and the Prioritization of Contract Management Tasks study, AFCMD/SM became aware that the entire SM program was not working out as AFCMD had intended. Both the AFPROs and the SPOs were having difficulty accepting the priorities of tasks outlined in the regulation, which put program support behind system evaluation and literally directed how the AFPRO subcontract managers would do their job. Feedback in the SM area obtained as a result of the Prioritization of Contract Management Tasks study was most unfavorable. Likewise, Command-wide staffing of a proposed revision of AFCMDR 70-24 in 1976 also brought a multitude of recommended changes and improvements. (4:1) At this point AFCMD/SM recognized it had to make some effort to bridge the communication gap with the program offices.

Also in 1976, AFCMD recognized that the CMSE Program was maturing and that the system evaluators, including SM evaluators, were becoming more efficient in reviewing elements of the contractor's procurement system. Documentation procedures and periodic reviews were taking less time, and more of the SM evaluator's time now was available to provide direct program support in concert with the ACO.

In July 1977, AFCMDR 70-24 was revised significantly in an attempt to eliminate the barriers between the SPO and AFPRO. The instructional guidance and priority arrangements which created animosity between the AFPROs and SPOs were removed. The AFPR was given the opportunity to become more active in subcontract management and was directed to establish his own priorities and procedures for SM activities. AFCMD/SM had recognized that more individualized interface with the

program offices was required and that the AFPR was the key person to insure the SM interface worked effectively. In subcontract management, the AFPR could now become more accommodating to the desires of the SPD and more sensitive to his needs for support. Once the CMSE Program was functioning smoothly, AFCMD recognized that it should permit its scarce SM resources to concentrate on the high priority, critical subcontracts.

<u>Hypothesis 2</u>

Now let us look at some of the causes for misunderstandings between the SPO and AFPRO concerning what is to be accomplished in SM. We know that the SPO has the initial action to obtain the needed subcontract visibility. This is where the contracts are written with the appropriate clauses to insure that the contractor has a Subcontract Management Plan and that he interfaces with the contracting officer or his representatives. This part of the job is done rather well in AFSC today. Where the effort begins to weaken is in the initial working relationships with the AFPRO. These good relationships must begin long before contracts are awarded or MOAs are executed. There must be an opening of the minds early in the program to determine what is required during the surveillance phase. The MOA is the vehicle whereby the SPO makes its desires known to the AFPRO. It is the charter wherein proposed SM activity is recorded. Unfortunately, experience shows numerous shortcomings in the SM appendices of MOAs.

It is also necessary to examine the position of the product division in cementing good SM relationships early in its programs. My informal survey revealed there is little dialogue between the product division and AFCMD on SM support to the program offices. Further, the development of MOAs is left strictly to the SPO and AFPRO. One product division SM focal point said he does not even know or see the agreements which are worked out between the two parties. As a result, the SPOs are developing their SM plans for CAS support without the benefit of the product division's past experiences. This becomes critical when one considers the small number of SM success stories within this Command. Hence we continue to plod along with SM planning while looking at the same type of information while disregarding the benefits of SM innovations developed by other SPOs. There appears to be a meaningful role for the product division staff in the development of MOAs, especially in SM. Much emphasis is placed on program documents such as Determination and Findings and Advance Procurement Plans which have much upward visibility, but little is placed on documents with lower-level involvement.

The next item of concern is the determination by the SPO of what it wants to be accomplished in SM during the contract surveillance phase. My review of nine AFSC MOAs shows that there was a lack of knowledge or desire on the part of both parties to iterate what was to be accomplished in SM, or that the SPO even knew what it wanted. In fact, four of the MOAs did not even address subcontract management. Current AFSC policy states that MOAs should not repeat verbatim instructions provided in other documents such as ASPR 1-406. They should, however, be quite specific and detailed in descriptions of the functions, methods and interface details for the tasks identified. The MOA should be used as the vehicle to identify and assign surveillance activities and reporting requirements for the AFPRO and SPO. (5:23) We are not complying with the intent of this well-founded and necessary AFSC policy. Simply stated, the SPOs are not putting enough words in the SM section of the MOAs to clearly express to the AFPRO what it is they want the AFPRO to accomplish. If the parties to the MOA cannot succinctly record what is to be accomplished, there is little wonder that confusion and misunderstanding result.

Also, personalities and experience play a significant part at this juncture. A program manager who has had experience in CAS operations will be much more sensitive to the AFPRO situation. He will know that his program is not the only one in the plant and therefore must be closely coordinated with the others. Likewise, the AFPRO must be aware of the program manager's experience and be flexible enough to accommodate his actions and busy TDY schedule.

Still another area of concern is the role of the AFPRO during the pre-MOA period. Too often, the AFPRO is content to await delayed inquiries from the SPO. If this situation develops, the AFPRO should begin to question the SPO concerning the planned extent of contract administration support to be

required. This should get the program manager thinking and force discussions between the parties. Also, the AFPRO should offer suggestions or possible avenues of approach to the SPO. It should tell the SPO what has been successful in the AFPRO on previous programs and what some of the results are. After all, the AFPRO has the experience. This approach, although sometimes overlooked, could provide the catalyst for an effective and smooth SPO/AFPRO relationship for the life of the program. Thus, before being committed to the MOA, each party would know fully the thoughts and desires of the other.

Hypothesis 3

As AF subcontract management professionals, how well are we recording our experiences for those programs which are to follow? Are we retaining the SM corporate memory and using it to the advantage of the program? I believe we are doing an inadequate job in the SM area, which is leading to unnecessary subcontract dollar expenditures on our major weapons programs. Retaining a good, SM corporate memory has been difficult because there are no known regulations or higher authority requiring us to do so. As mentioned in the discussion on Memorandums of Agreement, we move from one program to the next, taking but a few of the good SM lessons learned. The situation becomes a vicious circle, because the MOAs understandably will be weak in the SM appendix if there is not a strong corporate memory dictating what should be perpetuated in the MOA.

For a moment, let us review why the the corporate memory issue has been so elusive for SM. The SM corporate memory has been weakened primarily by three factors: lack of personnel experience and expertise; lack of emphasis placed upon subcontract management by the product divisions; and, apathy toward SM on the part of the SPOs.

In the first instance, the personnel aspect takes many forms. There is a definite lack of personnel with SM experience of any kind operating within the SPOs. This is understandable since most of the SM activity within DOD is conducted either by civilian ACOs, procurement methods analysts, or assistants for subcontracts in the AFPROs. Further, civilian personnel within CAS tend to transfer within that community and not into the buying offices. Accordingly, there is also a lack of personnel experienced in SM operations working on the product division staffs. Many have worked the procurement process but few, if any, routinely have worked SM problems. Also, key civilian personnel within both AFCMD and AFSC SM functions within the Command have been lost to transfer or promotion within the past year.

The second reason for a weakened corporate memory is the fact that within the product divisions today, SM is treated as an additional duty. This is somewhat surprising when one considers the millions of dollars spent each year by that division on subcontracted effort. Although the product divisions have taken an active and appropriate role in insuring that contracts contain the current SM clauses, they have done little to assist the SPOs in insuring that the SM process is run effectively and that the interface with AFCMD is running smoothly.

The last area is the need for emphasis to be placed upon SM by the SPO. In many cases, the SPOs do not know what needs to be accomplished in SM. Also, SM problems tend to be overshadowed by more important SPO issues such as system engineering changes, test program difficulties, and funding limitations. Therefore SM considerations usually receive less attention than others unless there is a catastrophic subcontract failure.

Several possibilities for accomplishing the restoration of SM corporate memory exist. The best SM corporate memory within AFSC today rests with the AFPROs. Here is where AFCMD has stored the wealth of its subcontract experts who have been dealing with prime contractors (in many cases the same contractor) for years. As mentioned in the MOA discussion, these are the experts who know what procedures worked with a specific contractor in the past. The SPOs must solicit the knowledge of these valuable AF resources to prevent the pitfalls of previous programs, along with the pain and cost of correcting these mistakes.

AFCMD has a responsibility to share among the AFPROs the lessons learned by each individual AFPRO. AFCMD has been less than forceful in this endeavor. As mentioned earlier, primary AFCMD emphasis has been toward systems management. Understandably, the distribution of SM lessons learned within AFCMD has dealt primarily with systems management. With the

satisfactory implementation of CMSEP throughout the Command, emphasis may shift more toward direct program support.

Also, the product divisions and AFCMD should establish a dialogue at the division headquarters level to discuss what has worked well in SM direct program support in the past. The author recognizes that this action might be more idealistic than realistic since the two headquarters staffs would have to overcome previous opinions concerning the other's approach to SM. According to the PMAG study, the parties will have to set aside preconceived barriers which inhibit effective communication. (3:14) Nevertheless, a complete and free-flowing dialogue in the form of a workshop (versus formal briefings) would create the necessary catalyst needed at this level to retain the SM corporate memory. The emphasis should be on how the operations can reduce the program risk and increase the subcontract visibility for the program managers.

The product divisions must identify the SM success stories and innovative techniques being employed today within their divisions and spread the word to the newly-formed SPOs. They must take an active part in soliciting this information from the SPOs.

I have presented four alternatives to assist in restoring the corporate memory. Implementation of any of these alternatives would assist the SM communication throughout the Command.

Conclusion

In conclusion, we have seen the need for greater subcontract visibility by the AF program manager, since visibility is the key to avoiding costly overruns. In AFSC, visibility has been inhibited by poor SM communication as shown by the hypotheses. To obtain the necessary visibility, the prime contractor must provide timely and effective management in its contractual dealings with its vendors. Likewise, the AFPRO/SPO team must use all the resources and ingenuity available to influence or assist the prime, when necessary, without violating the privity of contracts principle.

The analysis of Hypothesis 1 has presented a shift in emphasis by AFCMD toward greater involvement in gaining SM visibility. This has been manifested in AFCMDR 70-24 which now permits the AFPR more flexibility in supporting the program managers. Today there is a better atmosphere of mutual understanding and communication in SM between the AFPRO and SPO than ever before. The previous trend of erosion of direct SM support has turned around. However, the SPOs must take more positive action in making known their desires for subcontract administration support from the AFPROs.

Hypothesis 2 shows that the program office has taken a passive and sometimes apathetic attitude toward SM and has become involved only when a subcontracting crisis occurs. Lack of SPO personnel experienced in SM activities and constant reliance upon the AFPRO have been contributing factors influencing this attitude. This attitude is further demonstrated by the unenthusiastic manner which the SPO and product division staffs exhibit in dealing with the SM appendix of the MOA.

The Hypothesis 3 analysis concluded that the product divisions have not retained a good SM corporate memory and hence cannot provide meaningful SM experiences to the developing SPO.

The Hypothesis conclusions substantiate the existence of communication barriers in AFSC/SM operatings and represent what I believe are the three major, contributing factors inhibiting effective SM communication in AFSC today.

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USING OFF-THE-SHELF COMPETITION TO REDUCE THE COST OF GOVERNMENT

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INTRODUCTION

This paper focuses on policies and practices of the Federal Government in the purchase of commercial products. These are the thousands of products bought and used every day by the general public, industry, and nonprofit organizations, as well as by the Government. The thesis is that most of the Government's needs for commercial products can be acquired more effectively and cheaply by relying primarily on "off-the-shelf competition" than on solicitations based on Government specifications.

As a result of the language used in Federal procurement statutes and the implementing regulations, it has become traditional practice in Government to: Determine its needs. Describe them by writing purchase specifications in such a way that any potential supplier can produce the item. Request bids or proposals for products that meet the description. Award a contract to the supplier offering the lowest price.

The practice works well for special needs, but it is a costly way to buy products that are readily available on the commercial market. In addition to the cost of the process, the result is a hodgepodge of products made or modified to just barely meet the Government specification. This "competition by specification" is also limited to firms that are willing to compete in this manner.

The problem has been recognized in many Government studies including that made by the Congressional Commission on Government Procurement. As a result of the Commission's findings, the Office of Federal Procurement Policy (OFPP), Office of Management and Budget (OMB), issued a Federal procurement and supply policy requiring that: "The Government will purchase commercial, off-the-shelf, products when such products will adequately serve the Government's requirements, provided such products have an established commercial market acceptability. The Government will utilize commercial distribution channels in supplying commercial products to its users."

But how do you buy off-the-shelf products using timeworn Government purchase methods? The Department of Defense has established a "Commercial Commodity Acquisition Program" (CCAP) to find the answer to this question.

One difficulty in finding the answer is the Government's concept of competition. It is generally referred to as "adequate price competition." Guidelines in procurement directives to obtain price competition require offers that are responsive to a solicitation specifying or describing a minimum Government need. Therefore, many Federal officials still insist that negotiations based on prices established in the marketplace for off-the-shelf products do not meet the Government's concept of adequate price competition. The result is continuation of the complex and costly specification system for many products that could more effectively be purchased off-the-shelf.

However, a few Government activities have established prepriced contractual arrangements with multiple sources on the basis of established catalog or market prices. These arrangements cover off-the-shelf products for selection to fit the need at the user level. We believe that provision should be made in procurement statutes and directives to use off-the-shelf competition as a primary method of purchasing commercial products. Consolidation of requirements for competition by specification would only be used when warranted by significant total cost benefits.

Let us now review the needs of Government users for commercial products and compare "competition by specification" versus "off-the-shelf competition" in meeting these needs.

SATISFACTION OF THE USER'S NEED

The primary purpose of Government procurement and distribution systems is to provide the ultimate user with the supplies, equipment, and services required to accomplish a job or fulfill a need.

There are many users, especially in the Department of Defense that, by the nature or complexity of the equipment they need and the way it has to be supported, must be provided with products of special design or that must be of standard configuration. But most Government users are engaged in functions with needs that are similar or identical to those outside the Government. These are the commercial product users.

A survey of commercial product users by the Commission on Government Procurement [illegible] that their greatest concern is for [illegible] suitability, responsive delivery, [illegible] simplicity. Users invariably [illegible] Government procurement and support of commercial products with their own ability to buy the same kinds of items and services on the commercial market for their own personal use. Even though they become resigned to the "system" within which they must function, they are not satisfied unless their needs [illegible] more efficiently and economically than they believe they could do for themselves.

Many items are bought by the Government that are not suitable for a wide range of intended purposes. These items are not used effectively and many are disposed of as surplus without ever having been used. Where users know what off-the-shelf products are available that will best fill their needs, product suitability is an important consideration.

The most critical need for responsiveness is in parts and supplies needed in maintenance where requirements cannot be predicted. However, in filling any need, where the user knows that a suitable item is available from a local commercial outlet, delays occasioned by a lengthy purchasing or requisitioning process are irritating and costly. Yet the Government has established huge depot and distribution systems for commercially available items that only involve sporadic Government demands.

Most users know what they need and can easily communicate this requirement to a colleague, but they have difficulty in describing the need to the procurement community for purchase action. This problem lies with Government procurement requirements for specifying needs so that any potential supplier can respond by offering a product that will meet the specified need. But products made for the marketplace differ in form, function, and quality. The users believe they know (by experience or profession) the products in the marketplace that can best satisfy their needs; but procurement requires a nonrestrictive description of minimum Government needs to solicit offers from all potential suppliers.

COMPETITION BY SPECIFICATION

General policy on the use of specifications and purchase descriptions is provided in ASPR 1-1200 and in FPR 1-1.305. General policy is that Federal and military specifications, as well as industry documents adopted by the Government, are mandatory in the procurement of supplies and services covered by such specifications.

The term "adequate price competition" is referred to in the statutes as "full and free competition." In ASPR 3-807 and FPR 1.3-807, Pricing Techniques, the term is further defined as something that exists when (i) at least two responsible offerors (ii) who can satisfy the purchaser's (e.g., the Government's) requirements (iii) independently contend for a contract to be awarded to the responsive and responsible offeror submitting the lowest evaluated price (iv) by submitting priced offers responsive to the expressed requirements of the solicitation.

Compliance with these directives is achieved by solicitation of bids or proposals from all prospective suppliers to furnish products that meet the need. The supplier submitting the lowest priced item is generally awarded the contract without comparing value of products offered. Although the concept is straight-forward, the most important factor is item price with little consideration for total cost to the Government.

The procurement process is part of total cost. It includes an inordinate effort in: Quantifying requirements. Developing specifications or purchase descriptions. Soliciting bids or proposals. Evaluating offers. Making awards. And managing the resultant contract to assure delivery of products meeting the specification or description.

In addition to the administrative cost and the delays in delivery occasioned by complexity of the process, other actions occur that further increase total costs. Since the process is recognized by management as costly, and economy of scale is assumed, there is a strong tendency to reduce duplication by centralizing the function and consolidating requirements for many activities. Computing stock requirements in anticipation of requisitions frequently result in huge surpluses. Estimation and computation of needs for many activities, of a single product, takes months.

When development of a new product specification or description is required it may take a year or two from identification of a need to providing procurement with a complete purchase request. The contracting process can also take a year or more due to delays in complying with administrative requirements, particularly if protests must be answered. All this cost and time is considered to be a normal requirement of the process as dictated by Congress. There is no accounting for the cost to the taxpayer or relationship of total costs to benefits in using the concept of "competition by specification" in purchase of commercial products.

OFF-THE-SHELF COMPETITION

An alternative to the Government process of "competition by specification" is "off-the-shelf competition" for commercial products. The basic difference in the two concepts is that instead of asking industry to offer products meeting a Government specification or description, the Government acts as another customer for privately designed and developed products currently offered by industry in the marketplace. This is now done by the Government in making small purchases, in emergencies, and in several other indefinite delivery contract arrangements that are not expressly provided for in the procurement statutes or implementing directives.

The following programs are cited as examples of where off-the-shelf items are bought without use of product specifications by negotiating discounts from established market prices.

• Federal Supply Service multiple-award schedule program. This program was initiated by the Treasury Department over 50 years ago. It consists of a pricing arrangement with each manufacturer or supplier that sells commercial products in the marketplace who will provide these same products to any Government ordering activity at an agreed upon price. The value of orders under this program for fiscal 1977 was $1.5 billion.

Initial solicitation is for offers of entire lines of off-the-shelf products at a discount from established catalog or market prices. The offers are evaluated and negotiations are conducted with each firm that has a product the Government may need during the contract period. Award criteria is a price objective (benchmark) determined appropriate by the buyer in consideration of the anticipated volume of Government business and the range of discounts offered by competitors for the same range of products. The resulting contracts are made available to every Government activity for ordering needed items directly from the supplier without further negotiation. These using activities select the lowest priced item that will fill their needs from the multiple sources on contract.

• Department of Defense food supply bulletin program. This program is very similar to the Federal Supply Schedule Program but it is for processed foods that are purchased for resale through Department of Defense Commissaries. The solicitation procedures, negotiations, and resulting contracts may differ from multiple-award Federal Supply Schedules, but the concept of using off-the-shelf competition as a basis for contract pricing is the same.

• Air Force Buy U.S. Here (BUSH) Program. This program was instituted in 1962 to provide DOD activities located overseas with many off-the-shelf products covered by Federal Supply Schedules in the United States. The contracts are limited to those U.S. firms that have overseas distribution systems and can deliver and service U.S. made products to overseas activities more effectively and economically than if the items were obtained from the United States through Government distribution channels. The solicitation, negotiation and contracting practices established by the Air Force for this program are similar to those used in the Federal Supply Service multiple-award schedule program.

MULTIPLE-SOURCE CONTRACTING AUTHORITY

The FSS cites Section 302(c)(10) of the Federal Property and Administrative Services Act as authority to negotiate multiple-award Federal Supply Schedules. This exception to formal advertising is "for property or services for which it is impracticable to secure competition." An identical exception is included in the Armed Services Procurement Act.

Examples of when this authority may be used are given in the Federal Procurement Regulations (FPR) and the Armed Services Procurement Regulation (ASPR). These examples include cases where the supplies or services can be obtained from only one person or firm "sole source" and when it is impossible to draft adequate specifications or purchase descriptions for a solicitation for bids.

Unfortunately the wording of this exception and the examples for its use convey the impression that "competition" is not feasible when using this authority. Even the FSS refers to single-award schedules as competitive, inferring that multiple-award schedules are noncompetitive. But those managing the multiple-award program recognize it as being based on off-the-shelf competition with two additional competitive steps achieved, one in the process of contract negotiations and one in product selection at point of use.

Multiple-source contracts come under a type of contract defined in the FPR and ASPR as "indefinite delivery." These are prepriced arrangements for a period of time where the quantity is either indefinite or is dependent on Government needs. However, the FPR and ASPR do not provide for multiple-source indefinite delivery contracts. Instructions are provided in the directives for placing orders against multiple-award FSS schedules

but even there the ASPR indicates that non-mandatory FSS schedules are to be considered "another source of supply."

MEETING THE USERS NEED

The criteria for commercial product evaluation must be based on satisfaction of the user's need. Accordingly, suitability of the product for its intended use and responsive delivery must be considered along with ordering simplicity. Simplified small purchase procedures are currently provided for by statute and procurement directives for purchases under $10,000. However, in attempts to reduce the number of individual purchase actions by Government activities these purchases are limited to items that are not easily provided by a central depot type activity. Small purchases made at the point of use can be accomplished quickly and effectively without development of detailed specifications. But when small purchases are consolidated to exceed $10,000, they must follow the procurement process for competition by specification.

As the size of the purchase increases so does the cost of the process and the expectation of being offered off-the-shelf products is reduced. The cost of the process increases due to the time involved in estimating and consolidating requirements, preparing more detailed specifications, using greater care in technical evaluations, and in debriefing of unsuccessful offerors. The product offered in response to a solicitation may be an off-the-shelf item if one is readily available that meets the specification. But if the size of the order is large enough for separate production, a modified version of the off-the-shelf item that barely meets the specification will most likely be offered. There is no assurance that the item offered has the same quality, reliability or features of its commercial counterpart. When the quantity is large enough the solicitation also encourages bids or proposals from firms that do not make that particular item for sale in the commercial marketplace. Thus evaluation of products offered becomes increasingly difficult as the quantity procured increases, and the potential problems in maintaining the item also increase. Attempts to solve this problem by using performance type specifications are hampered by lack of credible procedures in comparing the value of items offered on large quantity purchases of commercial products.

The programs cited as examples of using off-the-shelf competition in purchase of commercial products all result in multiple source contracts. These contracts represent the range of products and services that the contracting officer believes will be needed during the contract period. They are all sold in substantial quantities to the general public. They have met the test of the marketplace for quality and reliability. They are not modified to meet a minimum government specification. They represent various quality levels as needed in the marketplace. Government users are familiar with these products through their own private use or by keeping up with technology as part of their professional or technical interests. These are the products that are referenced in trade journals and are used by the industry counterpart to the Government technician. They represent the latest technology in consumer products with attendant benefits of the latest consumer product safety requirements.

When the user (professional or technician) prepares a request for a commercial product he will identify those items that he is familiar with and knows that their quality and features meet his needs. When multiple source contracts have already been established for these product lines the user can contact the local purchasing office for information on those items covered by contract. He may then select the lowest priced item that fills his needs. The purchase request can then cite the item by manufacturers description or model designation without development of a specification. If other than the lowest priced item is requested it must be justified by the user. The requesting process is responsive, simple, and easily understood by users.

There is much concern by managers of centralized buying activities that central control is lost when user activities are authorized to select products to fit their needs. They believe that users will select a greater capacity or quality than they need. This may sometimes occur but with less frequency than when selection is far removed from the point of use. In fact, central buying by specification results in standardization that exceeds the need of all those users below the standard and those with needs above the standard will not use the item anyway.

The activity purchase office can quickly place a delivery order against a multiple source contract on a one page form. Many companies provide for these orders to be placed with a local retail outlet for more responsive delivery and customer service. In fact the purchasing office can even place the order by telephone and confirm it by the one page delivery order. The responsiveness of delivery is as fast as the user would receive if he made the purchase for his own use.

When users feel that they are a part of the selection process they are less inclined to find fault with the resulting product but this is not the only benefit when purchasing off-

the-shelf items. Multiple source contracts are designed to use the commercial distribution system so there is no Government stock to become obsolete, pilfered or lost. Deliveries are made from the same stock that serves industry and the general public so the product not only meets quality requirements of the marketplace but it probably comes with a commercial warranty. Further, the level of quality needed for a particular application can be selected since the entire line of each source is prepriced by discount from market prices.

The basic multiple source contract does not assure any sales so the companies must compete with one another continuously during the contract period. If service is poor or product quality drops for any company they will no longer be competitive. And fortunately the Government is not "locked in" on a long term contract arrangement for large quantities.

COST AND PRICE

One of the assumptions of the Government is that any reduction in unit price achieved by making large quantity purchases is a savings. Since there is no accounting for efforts expended in consolidating requirements, preparing specifications, solicitation, inspection, warehousing, distribution, and management of these activities, these costs are not considered in comparing alternative methods of acquiring commercial products.

The price negotiated on multiple source contracts is based on the terms and conditions of the solicitation. Price and discount offers are solicited for the commercial line of products. In the case of the FSS multiple award schedules no total quantities are established, orders are placed by thousands of ordering officers throughout the United States, and destination delivery is required to each user. A frequent criticism of multiple source contracts is that the system does not assure the lowest possible price for a given delivery and that the lowest priced item is not always selected for the specific need. The average size of each order as established on our user level survey was $531. Obviously the contract prices, including transportation costs, which cannot be determined at time of contract negotiation, are averaged so those larger user activities that are in urban areas can separately obtain better prices at the expense of isolated low-volume activities. Variations in the pricing structure for large users could be arranged without detracting from the advantages of the concept.

Selection of the least total cost item at the point of use is a judgment decision that can best be made at the local site to fit the specific need. These decisions have to be justified to the satisfaction of the contracting officer and the discipline for making the right decision is a responsibility of management.

In addition to the three competitive levels (i.e., marketplace, negotiated discount, and user selection), the pricing of multiple-source contracts is fixed for a period of one year. The exception is for reductions that are made in the basic market price from which discounts were computed and are subject to price reduction provisions. Therefore, the Government has the benefit of a fixed price for a year even though prices are rising in the marketplace. During periods of very high rates of inflation, such as during wartime, economic price adjustment provision can be included in the contracts.

CONCLUSIONS

- Product suitability, responsive delivery, and ordering simplicity, are criteria for evaluation of systems that provide commercial products to Government users.

- Procurement statutes have established Government purchase methodology for commercial type products that are effective in achieving low unit prices but the process is slow and costly and the products are likely to be of a quality that may not be the best buy for the Government.

- Purchase mechanisms are in use throughout the Government that benefit from "competition of the marketplace" by providing Government users the same products that are available to non-Government users. These procedures are not provided for in procurement statutes or in basic procurement directives.

- The total cost of purchasing by various methods is not generally known and is not considered in selection of purchase methods and techniques.

- There is a need for recognition in procurement statutes and procurement directives of purchase methods that are based on "off-the-shelf competition" and for consideration of the cost of the acquisition process as part of total cost to the Government.

- Recognition by the Congress and procurement managers of the potential for economy and effectiveness by increasing reliance on off-the-shelf competition would lead to improvement in procurement practices and increased use of the concept when it is the most cost

effective method. Institutionalization of the concept would significantly reduce costs of Government.

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THE COMMERCIAL ITEM SUPPORT PROGRAM (CISP) MATHEMATICAL MODEL

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INTRODUCTION

This study, performed by the DLA Operations Research and Economic Analysis Office (DLA-LO), examines the Total Support Cost for managing an item of supply under several alternative methods within the Department of Defense. The study emanated from a request of the Assistant Secretary of Defense (MRA&L) that the Defense Logistics Agency develop a plan for implementing a Commercial Item Support Program (CISP). A part of that plan requires mathematical formulas and costing procedures to compare the Total Support Cost of the various possible alternatives.

In 1972 the Commission on Government Procurement (COGP) published a report stating that the DLA overhead and operating costs were excessive. The COGP concluded that, "even without considering obsolescence, DLA support costs are significantly higher than those of civilian activities. This was said to be due to (a) the type of management required for military logistics support beyond that required for civilian systems, (b) the economic and demand characteristics of the items being supported, and (c) the high costs of inventory investment associated with low turnover [1].

The General Accounting Office (GAO) and the Office of Management and Budget (OMB) recently expressed similar criticism of DLA inventory management. In one report in August 1976, the GAO stated that the DLA manages many minor, low-use supply items which could be supplied more economically through commercial distribution systems [2]. Subsequently, the GAO reported [3] that by not using full cost accounting in its cost analyses, the DLA justified central stockage of these items. In addition, the Office of Federal Procurement Policy (OFPP) of OMB in May 1976 issued a policy statement requiring maximum use of the commercial distribution systems, asserting that commercial distribution systems were more economical than government systems. However, the GAO has recommended that the OFPP modify its policy to state that the commercial distribution system should be used only when it is cost/effective to do so. The Assistant Secretary of Defense for Manpower, Reserve Affairs and Logistics, ASD(MRA&L), and the DLA are in agreement with latter GAO recommendations.

Although these recent criticims emphasize cost at the expense of military support, they do have some basis and point to a real need for the DoD to justify economically central procurement and stockage. It is alleged that the DLA currently stocks many items which have wide commercial availability, do not require a military or Federal specification, for which private industry response time is sufficient to support military needs, and for which central procurement is too costly. Accordingly, the DLA has initiated two complementary major management programs to identify commercial items, examine the need for government specifications, and determine the most cost/effective method of management.

The Commercial Commodity Acquisition Program (CCAP) reviews Government specification items and offers the opportunity to (1) eliminate all unnecessary Government specifications for commercial products; or (2) use industry standards in lieu of Government specifications when a formal specification is required; or (3) "scrub down" the Government specifications to reflect the commercial product to the maximum extent possible when Government specifica tions cannot be eliminated. Items which can be purchased without the Government specifications will then be processed by the CISP.

The CISP seeks to identify items which have wide commercial availability and for which commercial support is most cost/effective. The DLA is currently developing guidelines to determine commercial availability through market surveys and local purchase testing of centrally procured items, and has prepared a comprehensive CISP plan.

THE STUDY

Objective. This paper develops the Total Support Cost (TSC) models to compare the economics of alternative methods of supply support. The models will be used to determine the least cost method to manage commercially available items.

Scope. The study essentially addresses six of the eight supply support alternatives identified by the ASD(MRA&L). These alternatives are listed below and correlated to their corresponding DLA Supply Status Code (SSC).

Item Management Alternative (IMA)	DLA SSC
Contractor Support	None
Local Purchase	2
Supply Schedule Support	None
ICP Delivery Order Support	3
ICP Prócurement on Demand	3
Central Stockage	1,A
Combined Management	1,A
Contractor Support	1,A

DLA SSC classifications are defined as follows:

SSC-A. Items coded in this management category are generally low demand or insurance items. They are infrequently demanded, generally high price items with long procurement lead times. A nominal quantity is stocked.

SSC-1. Items coded in this management category are demand-based centrally procured by the DLA, and generally stored within the DLA distribution system. (There is some storage of DLA-owned materiel in other DoD warehousing facilities.)

SSC-2. Items coded in this management category are local purchase items which are procured and stored by user activities or their supply support systems. The DLA provides only cataloging and sometimes contracting support. SSC-2 items may also be obtained through Contractor Operated Civil Engineer Supply Stores (COCESS) or Contractor-Operated Parts Stores (COPARS), in which case the DLA provides no contracting support [4].

SSC-3. Items coded in this management category are centrally procured and otherwise supported by the DLA, but are not positioned in DoD warehouses. Customer demands are satisfied by direct delivery orders placed on the contractor by the DLA. The Indefinite Delivery Type Contract (IDTC) is a common procurement instrument for these items. The DLA does not procure its assigned items through a schedule system such as the Federal Supply Schedule (FSS) system utilized by the GSA.

Other SSC Codes. At present the following categories are excluded and not considered in this analysis:

SSC-4. Military Assistance Program (MAP) items are centrally procured and stocked solely for MAP.

SSC-5 Reference only items used only for bid invitations, allowance lists, etc.

SSC-6. Terminal items, issue until exhausted.

SSC-7. Items coded in this management category are centrally procured and stocked for overseas requisitioners.

SSC-8. Government-Furnished Materiel (GFM) and Government-Procured Property (GFP) for use in manufacture of items.

SSC-9. Semiactive, potentially inactive, future stockage not authorized.

SSC-0. No status code.

Inventory Management Alternatives (IMAs)

IMA1 - Contractor Support. This alternative includes supply support arrangements such as the COCESS and COPARS. No specific cost model will be developed by the DLA. Each base/activity will compare the costs of contractor support with its current local purchase procedures to determine the most economical method of supply for decentralized items. The DoD will publish guidance on this subject.

IMA2 - Local Purchase. This alternative represents current local purchase practice. Local purchase is defined in the basic CISP plan and ASPR 1-201.28 as the authorized purchase of materiel, supplies and services by an installation for its own use or use of an installation activity logistically supported by it. Local purchase is not limited to the immediate geographical area in which the purchasing activity is located.

IMA3 - Supply Schedules Support. This alternative represents support by procurement from published schedules, analogous to the FSS maintained by the GSA. When this alternative is used, DLA Supply Centers (DSCs) initiate Indefinite Delivery Type Contracts and publish and distribute printed schedules worldwide to users. Installations would order from and pay directly to the contractor. This type of contract normally lists items; however, one contract may cover several items and a separate contract may be required for each of several manufacturers who may supply this same item.

IMA4 - ICP Delivery Order Support. This alternative includes as subalternatives DLA procurement instruments such as Basic Ordering Agreements (BOAs), Blanket Purchase Agreements (BPAs), and IDTCs. IMA4 is for direct delivery to the user with orders issued by ICP.

BOA is defined in the CISP plan and ASPR 3-410.2 as a written instrument of understanding executed between a procuring activity and a contractor which sets forth the negotiated contract clauses which are applicable to future procurement between the parties. The BOA includes a description of the supplies to be furnished or services to be performed when ordered and a description of the method for determination of the prices to be paid to the contractor. BOAs are often used for sole source items. There is no fixed price. The total agreement is for over $10,000. BOAs are explicit and become legally binding upon both parties. Each purchase is negotiated separately. Some automation is possible.

A BPA (ASPR 3-605) is a simplified method of filling anticipated repetitive needs for small quantities of suppliers or services by establishing "charge accounts" with qualified sources of supply. BPAs may be used for procurements whose individual delivery orders do not exceed $10,000 each. There is no fixed price. BPAs are much simpler than BOAs. Delivery orders for under $500 against a BPA are highly automated; SAMMS Automated Small Purchase System (SASPS I) which consists of a rotating list of suppliers is used and no competition is required. Above $500 BPAs are seldom used. Instead SAMMS Automated Small Purchase System (SASPS II) is used. At least two bidders are automatically sent Request for Quotes (RFQ) and subsequently a Purchase Order (PO) is issued. SAMMS is the Standard Automated Materiel Management System of DLA. When there are no exceptions by bidders, the evaluation is automated. Exceptions must be manually evaluated.

IDTCs includes the following type contracts:

Definite Quantity Contract. This type

contract provides for a definite quantity of specified supplies or the performance of specified services for a fixed period with deliveries or performance at designated locations upon order.

Requirements Contract. This type contract provides for filling all actual purchase requirements of specific supplies or services of designated activities during a specified contract period with deliveries to be scheduled by the timely placement of orders upon the contractor by DLA for designated items either specifically or by class of items.

Indefinite Quantity Contract. This type contract provides for the furnishing of an indefinite quantity, within stated limits, of specific supplies or services, during a specified contract period, with deliveries to be scheduled by the timely placement of orders upon the contractor by DLA for designated items either specifically or by class of items.

IDTCs are generally used for procurements whose total annual demand is equal to or greater than $10,000. There is a fixed price. In the near future, delivery orders against IDTCs will be automated in DLA.

IMA5 - Procurement on Demand. This alternative represents the current type of support given SSC-3 items in DLA. A purchase action is initiated each time a requisition is received. This alternative is designed primarily for support of low frequency items.

IMA6 - Central Stockage. This alternative represents the current type of support given DLA SSC-1 and SSC-A items. It consists of bulk procurements, depot stockage and issues for each requisition. Procurements can be small or large purchase, BPA, IDTC, SASPS I or SASPS II.

IMA7 - Combination Management. This alternative maintains central stockage to support high priority requisitions and supports priority group III requisitions by delivery orders against IDTCs. Hence, it is a combination of IMA4 (IDTC) and IMA6. This alternative envisions the support of priority groups I and II by filling such requisitions from stock. Priority group III would be filled by direct delivery. The intent is to minimize stockage while providing responsive service when needed. DLA would use IDTCs for filling priority group III requisitions and for placing orders for stock. In this case, IDTCs might be for less than $10,000 demand per year.

IMA8 - Contractor Storage. ICP arranges for purchase of fixed quantities of items from a contractor and for the same contractor to furnish services for receipt, storage, and issue based upon release orders from the ICP. Contractor storage is a separate issue and should be considered at a future date.

TOTAL SUPPORT COST

General. The total support cost (TSC) for an item of supply is the full cost incurred by the Government in delivering the item to the customer. As well as the price paid for the item, the full cost includes an allocated share of the cost of the support system used to acquire and deliver the item. Thus, both the market price paid under each procurement alternative and the overhead costs of the support system are directly included in the TSC concept. This definition is equivalent to the landed or full cost concept used by the GAO in its recent analysis [3]. The TSC not only includes funded costs but also certain unfunded costs, specifically the investment and obsolescence costs of inventory and the fringe benefit costs of civil service employees.

In the past, the TSC approach was a review of costs incurred, and an extrapolation of those costs as future expenses incurred through additional workload, or as savings accruing from reduced workload. It was, therefore, an average rather than incremental cost approach and has both significant advantages and disadvantages.

Average Cost and Incremental Cost Concepts. Two methods of considering the cost of managing an item are possible: (1) Average cost adds all costs and divides by the number of items managed. This method does not consider the characteristics of different items. It assumes that all items are managed at the same cost. (2) Incremental cost considers each item individually and computes the cost to manage based upon the variable workloads created by the item's characteristics.

Average cost and marginal (incremental) cost criteria are applied in quite different decision problems. If one is considering a relatively small adjustment to workload within an organization, i.e., one item at a time, marginal costs and marginal benefits will be compared to identify the cost-beneficial course of action. However, if one is deciding between the total population average, average cost may be used. The techniques applied by the COGP, GAO and recently ASD(MRA&L) have been based on average cost, for the reason that DLA support was compared with the total of local purchase and commercial support alternatives. If the total inventory management function were to be changed, the average cost method would apply. If only a portion of DLA item management is to be considered for change, the average cost does not apply. This paper examines the marginal cost approach.

Funded and Unfunded Costs. In order to determine the cost of DLA supply support, all Operating and Maintenance (O&M) costs for FY 76 were reviewed for applicability to the supply support mission. Applicable O&M costs were defined as all costs incurred in the support of items of supply assigned to DLA for item management. Costs associated with other

logistics missions were not considered in the calculation of the cost of DLA supply support. For example, all O&M costs of the Defense Industrial Plant Equipment Center (DIPEC), and the larger portions of O&M costs of the Contract Administration Services (CAS) mission and the Defense Property Disposal Service were not included in the cost calculations.

Whenever an O&M account was deducted as inapplicable, e.g., DIPEC, a prorated portion of other DLA resources expended in support of that account was also deducted. This procedure required a cost proration of all DLA management support organizations, such as the DLA Administrative Support Center (DASC), DLA Field Offices and the DLA Headquarters, to the Primary Level Field Activities (PLFAs) and the CAS mission.

These costs include applicable O&M as well as the unfunded costs of inventory holding and Federal employee fringe benefits. Other unfunded costs such as interest costs on cash balances, depreciation, and costs of alternative uses of land, equipment, and buildings, all of which may appear in economic analyses in the private sector, were not included in the cost rate. The rationale for these decisions relating to unfunded costs is discussed below.

Inventory Holding Costs. The major unfunded cost of DLA support is the cost of holding inventories. In this analysis the holding rate is applied to the actual inventory as reported in the quarterly stratification report.

The rate consists of three components: an interest charge of 10% per annum applied to the value of the inventory; a 1% storage rate, also applied to the value, which captures the depot O&M variable costs of managing inventory, exclusive of receiving, packing, issue and transportation functions; a variable obsolescence rate which is designed to recover the costs of decay in the demand process, or the percentage of the buy quantity which is lost to the obsolescence process at the time of the buy; and last, a miscellaneous loss rate. While DLA has set the miscellaneous loss rate at zero, it has calculated an obsolescence loss rate for each commodity, based on the value of the inventory sent to disposal.

The manner in which holding cost is applied depends upon the decision to be made. For purposes of estimating average total cost and fixed overhead cost, a conflict arises as to the use of actual costs indicated in DLA P350 cost account for storage or the 1% which is included in the holding rate in accordance with DoDI 4140.39 [5]. This study has considered these detailed costs and in the final analysis eliminates the P350 costs and uses 1% included in the holding rate.

As used in this analysis and for ease of application, the interest rate is applied against the value of annual gross sales.

Mobilization Reserve Stocks. Mobilization reserve stocks are not used to support current operations. Hence, they are not a consideration under CISP and are not included in the total cost support formulations.

Approved Force Acquisition Objective (AFAO). It is this strata which is budgeted for support of peace time demands. Recent analyses by the DLA Operations Research Office suggest that the demand decay is curvelinear. The study demonstrates that inventory has close to a 100% probability of being demanded during the first two years. If bought in larger quantities, the dollar value of which is low, the probability of it being demanded drops dramatically. Based upon this curve and the fact that at best these are approximations, no obsolescence is charged to AFAO; only storage and interest are charged.

Economic Retention. Based upon normal probability tables, the average probability of retention stocks being demanded has been determined. A separate curve was developed for each obsolescence rate. The cost of holding retention is computed as the loss due to obsolescence, the interest cost applied to the expected value of the materiel, and storage cost.

Excess. Excess materiel is to be disposed of; returned to the private sector. It is no longer a part of the DoD inventory. We have taken the loss by obsolescence in other strata. It is not included as a CISP holding cost.

In Transit. These are stocks which have been accepted by DLA at origin and are not yet in storage. They are included and charged interest only similar to AFAO.

Interest Cost on Cash Balances. As well as applying an investment cost to inventories, a private company would apply an investment cost to any funds which are not earning the potential return from an alternative investment. Any kind of revolving fund which has a net positive cash investment would incur an investment cost. DoD Stock Fund cash balances are maintained purely as book balances and, in fact, are not supported by actual cash on-hand. No funds are being withheld from the private sector; therefore, the study makes no charges for interest costs on cash balances.

Depreciation Costs. Depreciation accounting is used in the private sector to reflect the charge of fixed asset costs against current operations. Tax credits allowed serve as a mechanism to encourage private sector capital investments and thereby stimulates economic growth. For example, a private company will seek to recover the cost of storage facilities through depreciating the initial construction cost over a

given life cycle. A time stream of tax credits will then compensate, (more or less to the extent of actual costs) for this investment.

In government, the financing of major capital equipment and facilities is through congressional appropriation and there is no corresponding concept of tax credit which would offset this cost and thereby encourage investment in government. Cost/benefit analysis has been the major mechanism for evaluating government capital investments, and once funds are expended, the initial costs are sunk and therefore irrelevant to any future analyses. A private corporation would, however, show an annual cost due to depreciation; the annual cost would include the initial investment. Depreciation tax credits would appear as compensating revenues. There is simply no rational analogy for this type of financing in government. Consequently, no depreciation costs have been included as unfunded costs in determining the cost of DLA supply support.

Fringe Benefit Costs. Federal employees receive benefits which are costs on the aggregate Federal level, but these fringe benefit costs do not appear as O&M costs in budget statements of individual agencies. Consequently, fringe benefit costs must be added to the personnel cost component of O&M costs to determine the true cost of DLA supply support. The current total fringe benefit rate is 18.1%.

Opportunity Costs of Capital Assets. Another unfunded cost which appears in private sector cost analyses is the cost of the best alternative use of capital assets (land, equipment, buildings). These costs are generally labeled opportunity costs - the costs of alternative opportunities foregone by deciding upon a particular course of action. There is an opportunity cost associated with operating a depot if that depot has a private market value. Although the cost of foregoing sale of a depot to the private sector may be relevant, it has not been possible to identify the best alternative use of a Defense depot. Sale of the facility may not even be a feasible alternative let alone the best alternative. The opportunity costs of government-owned capital assets have not been included in the cost of DLA supply support.

THE MODELS

IMA2 - Local Purchase

$TSC2 = (P_2)(1-A_2)F+(1+R_b+Z)(V)(1+D_2)+(A_2)(F)(P_5+R_m)+L_2(K)$

where P_2 is cost of a procurement as a $f[(V/F)(1+D_2)]$ and has a different value dependent upon the value of the procurement. Where K is a $f[(V)(1+D_5)(A_2)/(1-A_2)]$.

IMA3-Supply Schedule Support

$TSC3 = I+P_3F+(1+R_a+Z)(V)(1+D_3)+L_1(K)$

where K is a function of the annual demand adjusted by the unit price differential $f[(V)(1+D_3)]$

IMA4 - ICP Delivery Order Type Contracts/Agreements

IMA4a - Basic Ordering Agreements (BOA)

$TSC4a = I_{BOA}+(P_{BOA}+R)F+(1+D_{BOA})(V)(1+R_a+Z)+L_2(K)$

where K is a function of the annual demand adjusted by the unit price differential $f[(V)(1+D_{BOA})]$

IMA4b - Blanket Purchase Agreement (BPA) also (SASPS I and II)

$TSC4b = I_{BPA}+(P_{BPA}+R)F+(1+R_a+Z)(V)(1+D_{BPA})+L_2(K)$

where P_{BPA} is a function of the dollar value of the procurement adjusted by the Unit Price differential $f[(V/F)(1+D_{BPA})]$. This same formula applies to SASPS I and II procurements; the value of P_{BPA} changes for SASPS II.

IMA4c - Indefinite Delivery Type Contract (IDTC)

$TSC4c = I_{IDTC}+(P_{IDTC}+R)F+(1+R_a+Z)(V)(1+D_{IDTC})+L_2(K)$

where K is a function of the annual dollar demand adjusted by the unit price differential $f[(V)(1+D_{IDTC})]$.

IMA5 - Central Procurement on Demand (POD)

$TSC5 = (P_5+R)F+(1+R_a+Z)(V)(1+D_5)+L_2(K)$

where K is a function of the annual dollar demand adjusted by the unit price differential $f[(V)(1+D_5)]$.

IMA6 - Central Stockage

$TSC6 = (J+S)F+B_i(V/Q)+(1+R_a+H)V+L_2(K)+I$

where K is a function of the annual dollar demand $f(V)$.

B_i varies dependent upon the procurement instrument used.

For regular bulk procurements, B_i = either the small or large procurement cost of B_1 and $I = \emptyset$.

For BPA or SASPS I, $B_i = B_2$ and $I = I_{BPA}$.

For SASPS II, $B_i = B_3$ and $I = I_{BPA}$.

For IDTC, $B_i = B_4$ and $I = I_{IDTC}$.

IMA7 - DLA Combination Management. In this alternative stocks are maintained to support the high priority demand base only (priorities 1-8). Low priority demands will be supported by IDTCs. Since it is unclear at this time how many storage facilities would be required to support a large-scale conversion to combination management, the same overhead cost has been applied. It is likely that the value of L_2 would increase in the event of large-scale combination management because overhead costs are not likely to be reduced in proportion to inventory reductions. Thus, the TSC7 formula is conservative.

$$TSC7 = I_{IDTC}+L_2(K)+(1-R_1)[(J+S)F+(1+R_a+H)(V)(1+D_{IDTC})]+(1-R_1)(P_{IDTC})[(V)(1+D_{IDTC})/Qc]+R_1[(P_{IDTC}+R)F+(1+R_a)(V)(1+D_{IDTC})]$$

where K is a function of the annual dollar demand adjusted by the unit price differential $f[(V)(1+D_{IDTC})]$.

Definition of Costs and Other Inputs. Values have been derived for all inputs required to drive the models. Some of our values are quite valid; others require further study. We have coded each input value with a Roman numeral, indicating its reliability: The higher the Roman numeral, the more reliable the value.

Code	Review
I	Currently under further study.
II	Values are best estimates based upon studies which have not been validated by DLA. These should be studied further at the earliest practical date.
III	Values are best estimates based upon studies which have not been validated by DLA. However, these values appear reasonable or are not vital to results.
IV	Values are averages and are the result of a DLA study. These should be examined further to determine if the averages apply in the extremes (high or low ranges), or if policy changes in the future would affect the average.
V	Values are the result of a detailed DLA study. Further study is not considered necessary except for some future update.

P_2 - Average administrative cost to procure at installation level. Costs are estimated to vary as a function of the value to be procured (the average requisition value). These values are under further study by the Military Services. (Code I)

F - Frequency of requisitions per item per year at the ICP. Formulas assume one order per requisition for other than central stockage and assuming no change in average on hand inventory. (Code NA)

R_b - Rate of annual holding rate of inventory to annual dollar demands . local installation when local management is used. (Code I)

Z - Rate of returns redistributions lost to the system per year when central stockage is not used (Code V)

D_2 - Average unit cost differential for local purchase vs. central ICP procurement. These values are under review by the Military Services and in addition are being tested by the CISP's Early Initiatives. The expression $(1+D_2)V$ is used to adjust the annual dollar demand by the unit price differential. (Code I)

V - Annual dollar demands of the item at standard price. (Code NA)

I - Cost per item on a supply schedule. A schedule may contain one item on a contract line or it may refer to an entire catalog of a manufacturer. It may be necessary to establish several contract lines for the same item when supplied by more than one manufacturer. (Code II)

P_3 - Cost of placing an order against an SS type contract (Code II)

D_3 - Unit price differential for FSS buy relative to stocked item buy. (Code II)

L_1 - Prorated ICP overhead for an SS type buy. Floor and ceiling values are used (Code IV)

L_2 - Prorated DLA ICP overhead costs per dollar demand by commodity. Application is same function as variable L_1. (Code IV)

I_{BOA} - Establishment of an item on a BOA. BOAs may accept all items a manufacturer or distributor sells. (Code IV)

I_{BPA} - Same as BOA (Code IV)

I_{IDTC} - Establishment of an item on an IDTC (Code IV)

P_{BOA} - Cost per order placed against a BOA using an automated system for a percentage of the items. (Code IV)

P_{BPA} - Cost of placing an order against a BPA. These are direct delivery costs. Automation is effective for below $500 procurements by BPA. Between $500 and $10,000, an automated system (SASPS II) is used. BPAs are not generally used in DLA for calls above $500. (Code V)[8]

P_{IDTC} - Cost of placing an order against an IDTC assumes automation, except Clothing and Textile, Medical, and Subsistence. (Code V)

D_{BOA} - Price differential estimated to be the same as for the FSS buy. (Code II)

D_{BPA} - Same as above.

D_{IDTC} - Same as above.

R - Requisition processing cost by ICP; includes installation cost. (Code V) [7]

R_a - Rate for holding cost of inventory investment component at the installation level when central management used. It is the ratio of holding cost of inventory to annual dollar demands at the installation level. (Code I)

P_5 - Purchase costs for procurement on demand, standard purchase order, for procurement values under and over $10,000 (Code V)

D_5 - Price differential for procurement on demand estimated to be the same as for the FSS buy. (Code II)

S - Depot overhead per line shipped. (Code IV)

J - Issue cost, includes installation requisition preparation and transmittal cost, ICP requisition processing cost, depot picking, packing, issue and transportation directorate costs, but not second destination transportation costs (already included in ICP price). (Code V)

B_1 - Procurement costs for stocked buys, includes receiving costs, for procurements under and over $10,000. (Code V)

B_2 - B_3 - B_4 - SASPS I and II vendor's lists for stock buys and include receiving costs (Code V). IDTC costs are manual (Code IV).

H - Holding cost rate by commodity as % of gross sales. (Code V)

R_1 - Fraction of the demand attributable to priority group III requisitions. (Code V)

Q - EOQ in dollars (Wilson).

Q_c - Reduced buy quantity in dollars for combination management. The value of Q = $k\sqrt{V(1+D_{IDTC})(1-R_1)}$

A_2 - Percentage of 2A requisitions to be received for an SSC2 item for each requisition formerly received for a stocked item (Code IV). (CT and S are based upon an average of the others as data was not available at the time this report was prepared.) Code II.

R_m - Cost to process a manual requisition (Code IV).

Impact by DSC. Based upon the values above, a computer program was run to test the models on each of the seven commodities. This program produces a matrix, generally as follows:

	REQUISITION FREQUENCY			
$ Demand	5	10	15	... .1000
5	x_1y_1	x_1y_2	x_1y_3	
10	x_2y_1			
15				
.				
.				
.				
100,000				

For each cell of the matrix, the total support cost of each alternative is computed. For example:

Demand		5 Reqn	10 Reqn
$5	LP	56	106
	SS	112	197
	BOA	NA	NA
	SASPS I	61	86
	SASPS II	NA	NA
	IDTC	96	121
	POD	460	893
	CS Proc	111	165
	CS BPA	NA	NA
	CS Automated	88	142
	CS IDTC	127	181
	Combined Mgt.	109	145

The manager, knowing the annual number of requisitions and the dollar demand, selects the least cost feasible alternative.

Review of test results. A review of tests made to date suggests:

a. The most significant factor in the decision between alternative management methods is the procurement costs. Automation for BPAs, vendors' lists and IDTCs is highly economic. Analyses of these tests strongly suggest that a central automated system is more effective than multiple local purchase activities.

b. Depot stockage results in variable processing costs, depot overhead costs and holding costs. Depot costs increase with increased number of shipments. These are the costs we would be transferring to the commercial distributors by using the commercial distribution system instead of DoD depot stockage. We might expect some increase in the unit price to offset this increased cost. Sensitivity testing suggests that direct delivery unit price would have to be 15% higher in order for it to outweigh the depot stockage costs; and then that would only be for low frequency requisitioned items. It would require over 25% differential to make depot stockage of a significant number of items economic.

CONCLUSIONS

CISP

1. Greater use should be made of the Commercial Distribution System (BPAs, IDTCs) by Defense Supply Centers.

2. Economics alone can justify stockage only in certain cases. Military stockage should not be based upon economics alone.

3. Local/installation management is not necessarily the most economic method of item management, particularly for high frequency demand items.

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FORWARD PRICING ARRANGEMENTS

"COMMON SENSE"
(Small Purchase)

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INTRODUCTION

During FY 1975 OO-ALC D/PP Management determined to take unique and positive action in the small purchase area (PL 93-356 = $10,000). The main thrust of management's drive was directly placed upon:

1. Excessive administrative costs
2. Increased workload
3. Reduced manpower allocations
4. Negligible return in negotiated savings
5. Customer (D/MM) unsatisfactory "fill rates"

D/PP Management was faced with "a disproportionate decrease in human resources being expended on sole source, small purchases with minor returns in the form of negotiated reductions and corresponding 50 + days of administrative lead time that contributed to the unsatisfactory "fill rate" of our assigned weapon system."

The first part of Ogden's D/PP five part problem namely excessive administrative costs, is shared by all in DOD as can be seen from ASPM #2, 31 Mar 1976, ". . .if each of these actions were to cost $100 in administration, DOD would be spending $1 Billion to buy $4.8 Billion. . . ."

The second and third parts of D/PP Management's problem are illustrated: FY 1975 Central Procurement contractual actions:

Actions:	Under $10,000 -	20,457		84%
	Over $10,000 -	3,798		16%
Total		24,255	=	100%
Dollars:	Under $10,000 -	$32,706,488		8%
	Over $10,000 -	402,167,815		92%
Total		$434,874,303		100%

Central Procurement authorized allocations FY 75 first quarter 367 ea vs FY 76 first quarter 350 = 17 ea allocation reduction.

Note: Salient point from the above - 84% of our contractual actions spent 8% of our procurement dollars and with reduced manpower allocations.

The fourth part of the problem was analyzed with J041 statistic Sample Cycle 4 information which showed:

Period	12	Months
Universe	$4,669,230.07	
Qty	3,666	actions
Sample	$466,052.03	
Qty	369	actions

Of the sample (369 actions) only 58 ea had negotiated amounts of $6,158.15 or a negligible negotiated savings (reduction factor of 1.3%)

The fifth part of Ogden D/PP problem is shared throughout USAF and probably DOD and is due to our aging weapon systems (out of production), increased flying or on-line time, and need for the related spare parts. Compounding this is the increased administrative or procurement lead time which then delays the contractor delivery date to satisfy our "fill rate" date of PRs.

STUDY

The entire purpose of this study was to innovate a completely new concept in the small purchase area that would: Remove all administrative lead time (issue same day requirement received) reduce administrative costs, and result in satisfactory earnings to industry and fair satisfactory prices to DOD that would withstand congressional or any/all public review.

By reducing procurement lead time, improve the contractor's delivery time which would improve our customer's "fill rates."

The first phase of our study was conducted with our high volume major suppliers of sole source replenishment spares, namely, McDonnell Aircraft Co (MCAIR), St Louis MO - F/RF-4 Spare Parts; The Boeing Co, Seattle WA, and Rockwell International Corp, Autonetics Group, Anaheim CA on our Minuteman (M/M) Spare Parts. During the period Dec 1974 through Jan 1975 MCAIR received contracts in the following dollar categories:

$100 - $2,500	=	121 ea
$2,500 - $5,000	=	22 ea
$5,000 - $15,000	=	30 ea
$15,000 - $50,000	=	16 ea
Total	=	189 Contracts

As can readily be seen, MCAIR received a preponderance of small purchase contracts resulting in a parallel situation of disproportionate expenditure of their resources.

The second phase was to flow the procurement process through our major suppliers (using MCAIR as an example). Steps:

1. Buyer would receive small purchase PR.
2. Prepare solicitation and mail.
3. Buyer would follow up with TWX' and telecons.
4. MCAIR would take up to 30-45 days to respond.
5. Buyer would attempt analysis and negotiation without certified cost data.
6. Buyer normally would request an extension of quote while in the "tug of war" for cost data on these small purchases.
7. Confirming wire received on price and delivery.
8. Price documented on small purchase PNM, DD Form 1784.
9. Contract submitted for PCO review.
10. Contract issued.

The above ten steps took an average 50 to 70 days of administrative time.

The third phase was to determine if valid past prices were readily available so that the buyer could, upon receipt of purchase request (PR), apply a time factor, utilize the past delivery information for the part number on the PR and issue a small pre-priced purchase order contract the same day as PR is received without a solicitation to the contractor and doing away with Steps 2-8 of above. For example:

Steps 2-8

PR | RFQ QUOTE EVAL NEG DOC | AWARD

ELIMINATED
if
the buyer has a valid prior price to use in conjunction with a negotiated forward pricing factor.

In this third phase, different methods were used in establishing the past base prices as being valid for forward pricing purposes.
MCAIR: Approximately 700 part numbers were substantiated with cost analysis and audit and negotiations due to a MCAIR cost accounting change (Analog 12+3, 1974); therefore, valid past prices for these 700 part numbers were available.
AUTONETICS: Two job orders - concurrent spare parts and nonconcurrent spares were verified in total which showed a loss/marginal profit to the contractor. A statistical sample of part numbers was verified with the cognizant field AFPRO office.
BOEING CO: Statistical sample of part numbers were verified by the cognizant AFPRO office as being the latest actuals (per part number accounting system).

The fourth phase centered on a pricing formula which could be applied to "past" prices which would consider the difference in time and result in "present" day prices. Method developed:

MCAIR: Sample common parts across all F-4 series were priced to a past vs current posture. To this posture was added a limited set up factor (compensate for tailing down of production of aircraft) + current rates vs past time rates were applied and difference between computations resulted in the yearly time factors.

AUTONETICS: Different years of pricing history were re-estimated to current pricing conditions which included updated vendor quotes. Difference between yearly estimates became time factors to apply.

BOEING: Unique situation - cost breakdowns always provided regardless of dollar value. Therefore, past cost breakdowns are used adjusted to current PR quantities and negotiated ACO forward pricing rates are applied; contracts are issued.

The fifth phase concerned controls on the pricing arrangements:

Objective: Equitable earnings to contractor and with Government protection was achieved by:

Cost segregations by quarters/semi-annual by our ALC contractors. Contractor's reserve right to perform a reasonable check on contracts received by performing a current internal estimate based on current plant conditions and rates. If total internal estimate is within + or - 5%, then contract price is firm; if not, contract adjusted (Autonetics and Boeing Co). Twice yearly cost vs contracts issued are reconciled if earnings are within + or -5% of target earnings; no adjustment made. If outside of tolerance factors, adjustments are made to the time factors or voluntary refunds are made by MCAIR (only).

RESULTS

Ogden D/PP, under this unique concept, has issued contracts (which our three above contractors would accept without solicitation, not knowing what part number or quantity was being contracted for) in one day with a minor amount of administration costs which removed the administrative lead time and consequently contractors delivered in a shorter period which was greatly more responsive to the PR need dates.

VOLUME & STATISTICS (as of Feb 78)

Contracts issued	2,568 ea
Dollars contracted	$9,612,837
Average contract value	$3,743
*Average days to issue	14.6
% of delivery changes	22.8%
% errors made	5.2%
Dollars credited back to 00-ALC	$415,000

*from PR receipt to contract distribution considering routine handling From 50 + days to

15 or 70% improvement. Could be 100% improvement since capability is there for one day issuance. MCAIR has reduced estimators (lower overhead).

By immediate placement of orders under $10,000 (upon receipt of purchase request) allows USAF to compress the procurement lead time and actually shortens the production lead time which substantially improves contractor's delinquency rates. The administrative costs, i.e. proposal preparation, reviews, reproduction, transmittal including postage, TWX' transmitting supporting data, or extending quotations and negotiation telecons all have been saved on the 2,568 ea contracts issued as of Feb 1978.

Cost savings of personnel have been realized in the estimating department (MCAIR). Contractor has applied his estimating talents to the larger, more complex procurement proposals. Further, new program proposals are being prepared with the existing personnel (to our knowledge). Instead of potential sales in this area, the contractor now has firm sales, as each 1155 and or priced order is a contractual instrument to proceed.

Discussions with our contractors indicate firm sales vs potential sales is a very significant asset, not only to themselves but to their vendors, also significantly impacts deliveries.

for example:
MCAIR (Data thru Jul 76)

	1st Qtr	2nd Qtr
Nr M contracts	172	241
Nr Line items	202	284
Of the line items	39 - FMS	34 - FMS
Items delivered early	131 - 70%	177 - 72%
Items delivered late	18 - 10%	11 - 5%
PR required delivery:		
Early	78 - 50%	138 - 78%
Late	38 - 24%	13 - 7%

	CUM Thru Jul 76 Boeing	Thru Jul 76 Autonetics
Nr Contracts	135	102
Nr Line items	143	107
Item with deliveries	78	34
Items delivered early	78 - 100%	34 - 100%
Items delivered late	0	0
PR required delivery:		
Early	65 - 83%	32 - 94%
Late	13 - 17%	2 - 6%

Under this unique concept, OO-ALC D/PP has:

Reduced administrative costs to both D/PP and the various contractors which has considerably shortened the procurement lead time given to the contractors for production time and consequently, has improved delivery times; also improved the "fill rates" of assigned weapons systems.

"Spin out" benefits. Subcontractor delivery and prices were notably improved due to firm contract requirements rather than a "what if" quotation condition. Flow time value: AFLC-wide one day stock fund equals approximately one million dollars in inventory.

Initially OO-ALC D/PP held these agreements to a threshold of $10,000 per line item (contract). This was expanded to $25,000 per line item. As refunds and adjustments were made and statistics proved that these arrangements were working, benefits (verified) were occurring.

Current plans include contact and preliminary work completed with the following potential contractors:

Westinghouse Electric, Baltimore MD - APQ 120

Chicago Aerial, Barrington IL - Camera Systems

Texas Instruments, Dallas TX - Radar Systems

Further plans are to raise the threshold to $50,000 then $100,000 as inflation continues and manpower decreases and the benefits of this method of procurement are further proven.

REFERENCES

(1) ASPM #2, 31 Mar 1976

(2) ASPR 1-109.1

(3) ASPR 1-312

(4) ASPR 3-807.3(g)(1)

(5) ASPR 3-807.12

(6) ASPR 16-813

(7) JAG Legal Opinion, 28 Mar 1977

(8) J041 E9RM

(9) Manpower Source List

(10) PL 93-356

(11) RCS LOG PP(Q)-7402

MILITARY SYSTEMS ACQUISITION IN A COMMERCIAL WORLD

Lt Colonel Lee A. Rigby, Deputy for KC-10 Joint Program Office

KC-10 PROCUREMENT OVERVIEW

The KC-10 (also, Advanced Tanker/Cargo Aircraft (ATCA)) program began during the 1967-1970 time period when both the Air Force's Strategic Air Command (SAC) and Tactical Air Command (TAC) recognized a requirement for increased air refueling capability. The Air Force, therefore, conducted a study of advanced tanker design options which emphasized new aircraft capabilities and costs. All new design options were found to be cost prohibitive. In 1971/1972, flight tests were conducted to determine the feasibility of converting an existing wide-body commercial aircraft into a military tanker aircraft. Simulated refueling hookups were completed using a modified B-747 aircraft and formating tests were completed using a DC-10. Simultaneously, renewed interest developed in an advanced capability cargo aircraft. As a result of these activities, the Air Staff issued a Program Management Directive (PMD) to the Air Force Systems Command (AFSC) in February 1974. The PMD directed the acquisition of a commercial wide-body freighter aircraft modified only as necessary to provide an air refueling capability, and fully exploit the aircraft's cargo carrying capability commensurate with the inherent design of the aircraft and the existing fuselage structure. Additionally, AFSC investigated the cost and modifications required to provide a commercial wide-body freighter aircraft with oversize and outsize cargo capability. It also made a comprehensive survey to assess the ability of industry to provide a full range of logistic support. After going through two starts and stops between 1974 and 1976, the procurement process for the program was finally initiated in early 1976. The Request for Proposal (RFP) for acquisition was released in August 1976 and the RFP for the contractor logistics support program was subsequently released in September 1976. The source selection process was suspended in February 1977 due to the elimination of funding from the President's proposed FY78 budget. After a six-month delay, source selection resumed in August 1977 and was completed in December 1977 with the award of both the acquisition and logistics support contracts to the Douglas Aircraft Company. The aircraft system was subsequently named the KC-10.

GENERAL PROCUREMENT APPROACH

From its inception, the KC-10 program has been characterized by an innovative approach and the development of new acquisition and logistics support procurement methods. One of the most revolutionary steps taken by the KC-10 Program Office was the decision to procure contractor logistics support of a major weapon system concurrent with the procurement of the system itself. This decision was based on the conclusion that concurrent procurement would force early consideration of support requirements in the acquisition contract, encourage maximum competition for the logistics support contract, and foster innovative support proposals. Additionally, more accurate life cycle cost estimates for aircraft selection purposes would result because actual support costs would be known.

The overall approach to the acquisition of the KC-10 was also novel in that the Air Force set out to find an existing aircraft that met its needs in lieu of designing, building and testing a system from the "ground up." The Boeing 747 and the Douglas DC-10 freighters were considered in order to take maximum advantage of commercial investment existing facilities and an on-going production line. The aircraft competition was limited to FAA certified wide-body freighter aircraft to reduce the Government's development investment required to qualify other wide-body manufacturers. An FAA certification requirement was imposed to allow the Air Force to take advantage of existing commercial investment, design, production and quality control concepts, thereby reducing overall costs. The choice of an FAA certified freighter also insured that commercial maintenance systems were already in existence. By limiting the selection to a derivative of an aircraft in active commercial service, the Air Force assured that benefits of spares pools, existing repair facilities, trained repair specialists, etc., would be available to support the aircraft.

The decision to procure logistics support concurrently with the aircraft acquisition presented the Air Force with some interesting problems. Contractors were being asked to develop a logistics support program that would provide support for an unknown type and quantity of airplanes located at an unknown base or bases. At first glance, the problem seemed baffling, but further research revealed the task could be accomplished. The methods used to accomplish this task will be explained in more depth later in this report.

KC-10 SYSTEM ACQUISITION PROCUREMENT

The KC-10 Acquisition Contract is for the production engineering (nonrecurring), test and

production of the KC-10 system. In addition to the effort required to modify the commercial DC-10-30CF aircraft into a KC-10, the following additional tasks will also be performed:

a. Initial aircrew training.

b. Predelivery test program.

c. Logistics support for predelivery test program.

d. Program management and systems engineering.

e. Data, technical orders and manuals required for the KC-10.

f. Provide KC-10 peculiar support equipment.

The overall philosophy, as stated above, was to take maximum advantage of the existing commercial wide-body aircraft investment, experience, resources, and business structure. Additionally, a contractual program was desired which would provide flexibility to accommodate future funding fluctuations without requiring aircraft price renegotiation. Therefore, the following ground rules were established for the KC-10 acquisition procurement:

a. Existing commercial practices would be used to the maximum extent possible even on the military modifications. This would include business as well as technical and management considerations.

b. Federal Aviation Administration (FAA) type certification would be obtained on the total aircraft. This would include certification of the military modifications.

c. Military peculiar modifications to the basic commercial freighter would be made in-line.

d. Military specifications and requirements would be held to a minimum.

e. All nonrecurring costs would be incurred during the first two fiscal years of funding with no cancellation costs remaining at the end of any year. Such an approach would enable the Air Force "to bite off" a little piece of the program at a time without incurring a large termination liability. To do this, the contract strategy and structure provided for discrete efforts for each fiscal year with no obligation to start the next year's effort.

f. An aircraft Unit Price Matrix (UPM) would be included to provide aircraft prices accommodating varying fiscal year funding levels. This UPM established firm in-base year 76 dollars for each of two to sixty aircraft. Thus, with each fiscal year, the Government has the flexibility to purchase varying numbers of aircraft at a predetermined price.

To insure the solicitation provided adequate opportunity to propose commercial practices, copies of the RFP in draft format were made available to each contractor for review and comment. A source selection team subsequently visited each contractor's facility to discuss RFP improvement/refinement suggestions. Simultaneously, an internal Air Force review of the draft RFP was conducted to resolve significant issues. The result was the release of an RFP which provided optimum contractor flexibility to propose commercial arrangements and procedures while still retaining the integrity of the Air Force's requirements. The draft RFP process also greatly enhanced the contractor's understanding of the overall procurement, resulted in the submission of complete and comprehensive proposals, and greatly facilitated the overall source selection process.

The source selection was conducted following the provisions outlined in AFR 70-15, "Source Selection Policy and Procedures." The Secretary of the Air Force was the Selection Authority for both the acquisition and logistic support efforts. The Source Selection Advisory Council was jointly organized under an Air Force Logistics Command chairman and an Air Force Systems Command deputy chairman. Further, the Source Selection Evaluation Board was formed with resources from the Joint Program Office forming the nucleus. People were drawn from many Air Force commands and placed on the technical, operations, logistics, management, contracts, test and cost panels.

Selection of the KC-10 aircraft was based on an integrated assessment of evaluation areas set forth in the RFP utilizing formal source selection procedures. The selection was based on the evaluation of all areas, including capability, cost (including life cycle costs), management and production systems, technical risk, supportability and schedule. "Terms and conditions" were also evaluated, including evaluation items for each offeror's overall business arrangement and certifications and representations.

An initial contracting obstacle was the development of a procedure for equalizing the disparity in price and capability existing between the two candidate aircraft. It was determined that normalcy in the competition could be achieved by stating "funding bogeys" in the RFP for FY77-82 based on the Five Year Defense Program (FYDP). This profile was referred to in the RFP as the "green line" profile. The contractors then used this profile to bid the maximum number of aircraft that

could be provided each fiscal year after all nonrecurring engineering and test effort was accomplished. The resultant aircraft quantities and their inherent operational capability were then compared in the performance of specified missions in the evaluation process. Based on the fiscal year structure used in the solicitation process, the acquisition contract was eventually structured in the general format graphically summarized below:

CONTRACT YEAR	YF FUNDING	ITEM SUPPLY	PRICING STRUCTURE
Basic	FY-77	Initial Nonrecurring	Firm Fixed Price
Option 1	FY-79	(1) Complete Nonrecurring (2) First Aircraft (3) Predelivery Test and Follow-on Test Support	Firm Fixed Price
Option 2	FY-79	Production Aircraft	Firm Fixed Price
Option 3	FY-80	Production Aircraft	Fixed Price with Economic Adjustment
Option 4	FY-81	Production Aircraft	" " "
Option 5	FY-82	Production Aircraft	" " "
Option 6	FY-83	Production Aircraft	" " "

In addition to the unique approach of providing a quantity of aircraft for a given Government investment versus pricing a specific aircraft quantity, the solicitation also offered each offeror the opportunity to propose commercial provisions which were consistent with their existing business structure. This approach was referred to as the contractor's "Best Business Arrangement" and was an evaluation item in the source selection process. The Government formulated "Best Business Arrangement" objectives to evaluate the contractors' proposals against. All terms and conditions proposed were assessed for reasonableness and acceptability. Commercial provisions proposed were generally accepted, with negotiations concentrating on tailoring them so as to be acceptable within the general framework of Government procurement rules and regulations. A brief summary of several of the more significant contract provisions and features follows:

a. Federal Aviation Administration (FAA) Requirements. This provision stipulates that the KC-10 aircraft must be FAA certified and sets forth the FAA certification documents associated with the aircraft's development and production which must be provided. Another provision of the contract, "Configuration Management," also requires that changes in FAA certification requirements will be incorporated in each undelivered aircraft at no change in contract price, if affecting all wide-body aircraft and promulgated within 18 months after contract award, or unique to the DC-10 regardless of when promulgated. This approach is considered consistent with commercial aircraft procurements.

b. Special Data Provisions. This provision sets forth the rights that shall be provided with all data delivered under the contract. All data associated with KC-10 peculiar requirements generated under this contract shall be provided with unlimited rights. All other data shall be provided with special rights which shall permit its dissemination by the Air Force for competitively procuring all future logistics requirements for any Government-owned DC-10 type aircraft, with the exception of parts manufacture.

Economic Price Adjustment (EPA). Option aircraft for FY80-83 are priced in FY76 base year dollars. The contractor proposed their commercial EPA clause to adjust base year prices to the time of aircraft delivery. The clause adjusts the airframe and engine prices individually. The Airframe and engine base year prices are adjusted by the following established indexes:

	INDEX	WEIGHT
Airframe	Average Hourly Gross Earnings Per Production Worker on Payrolls of Nonagricultural Establishments - Durable Goods (SIC 3721)	.75
	Wholesale Price Index of Industrial Commodities	.25
Engine	Hourly Earnings of Aircraft Engines and Engine Parts Production Workers	.333
	Industrial Commodities Index	.333
	Metals and Metal Products Index	.333

d. Special Progress Payments. All payments for nonrecurring effort shall be made pursuant to normal Armed Services Procurement Regulation (ASPR) progress payment procedures. Production aircraft will be paid for pursuant to a predetermined payment profile based on estimated in lieu of actual costs. This profile is based on historical cost accumulation experience associated with the fabrication of a commercial DC-10. The contractor is required to provide a certification that payments made at any point in time do not exceed 80% of costs incurred to date.

e. Warranty and Service Life Policy. Douglas proposed their standard commercial Warranty and Service Life Policy to cover all aircraft and other deliverable equipment. The logistics support contractor can act on behalf of the Government in using all warranties. Douglas expanded their general warranty coverage from 2 years after aircraft delivery to 5 years to be compatible with projected KC-10 usage factors, 1-1/2 hours per day, 540 hours per year. Design defect warranty coverage has also been provided for a 24 month period after aircraft delivery, with all defects also to be corrected in all undelivered aircraft. The service life policy provides coverage on selected airframe components for 10 years/30,000 hours and selected landing gear components for 10 years/30,000 hours/20,000 landings. Adjustments under the service life policy are made on a "prorated" cost basis. The warranty includes several KC-10 peculiar structural components in addition to the items normally covered under their service life policy for the commercial aircraft.

f. Most Favored Customer Warranty. This warranty is a contractor commitment that the price charged the Government for the basic aircraft portion of each KC-10 shall not exceed the price charged any other commercial customer for the same basic aircraft model delivered during the same time period. The provision also provides similar price protection for catalog spare parts, standard commercial aircraft changes, and aircraft changes required to meet FAA certification requirements in all undelivered aircraft.

g. Follow-on Price Warranty. This provision is a contractor commitment that the Air Force will continue to receive most favored customer status as defined in each contract's Most Favored Customer Warranty provision in any future KC-10 procurements.

h. Options. This provision sets forth the options provided to the Government for purchase of production aircraft. It provides latitude to purchase aircraft through FY83 at predetermined base year FY76 prices. The Option clause sets forth two option environments. The basic (Green Line) option quantities and prices are set forth by fiscal year and are based on the RFP's Green Line funding profile. This option arrangement provides for the procurement of 20 total aircraft. In the event different quantities are ordered in any fiscal year, aircraft are purchased from the UPM which results in different prices dependent on the quantity of aircraft procured. The Matrix includes individual base year prices for a quantity of 2 to 60 aircraft. The contractor priced each aircraft using the following formula: Commercial airframe base price + KC-10 peculiar base price - airframe discount = net airframe base price + engine base price = total net base price. The pricing structure is consistent with commercial aircraft pricing arrangements. The UPM affords the flexibility to procure varying quantities of aircraft depending on fiscal year funding available. All options must be exercised by 1 December of each year. They must also be exercised consecutively and for at least the minimum quantities set forth in the contract.

i. General Provisions. The KC-10 contract contains essentially the general provisions required by the ASPRs, except where minor deviations were granted. In addition, certain general provisions have been made applicable to KC-10 peculiar requirements only. These provisions (e.g., Cost Accounting Standards, Administration of Cost Accounting Standards, etc.) are not applicable to articles whose prices are based on commerciality (i.e., DD Form 633-7) and were so limited.

j. Quality Assurance and Manufacturing Processes/Procedures. Quality assurance and manufacturing shall be accomplished in accordance with the contractor's FAA approved quality and manufacturing systems. It was determined that the existing approved FAA systems in both areas were consistent with applicable Government requirements.

k. Testing. The aircraft testing will be accomplished by the contractor during a six month period between April and October 1980 on the first KC-10. Air Force testing will be limited to those changes required to convert the DC-10 to a KC-10 and insure that all specification requirements are achieved.

l. Spares Acquisition Integrated with Production. Provisions were included in the acquisition contract to require the contractor to reduce the acquisition price of KC-10 peculiar spare parts and improve logistic support by (1) concurrent ordering of certain selected spare parts with the end item to take advantage of quantity and production economies, and (2) securing proposals for firm prices for spare parts to be supplied to the Government as investment material.

KC-10 LOGISTICS SUPPORT PROCUREMENT

Under the KC-10 logistics support concept, the contractor is responsible for the majority of the KC-10 support effort. The contract support arrangements are predicated on operations being conducted primarily from a Main Operating Base (MOB) with short duration staging operations possible from other bases. Longer duration deployments involving establishment as operations/maintenance capabilities at forward operating locations are not contemplated. The supply support concept is for the contractor to support KC-10 spares requirements from a Contractor Operated and Maintained Base Supply (COMBS) activity located on the MOB. The contractor may use any available commercial source when support for the KC-10 is required away from the MOB. The Air Force is responsible for the overall KC-10 maintenance management effort as well as organizational and intermediate level maintenance. Specifically, the work performed by Air Force personnel falls into six categories; preflight check/inspection, turnaround check/inspection, postflight/servicing inspection check, routine phase check, minor corrosion control check, and nonroutine/corrective action maintenance. The contractor is responsible for all other intermediate and all depot level maintenance functions.

In order to solve the uncertainty problem caused by the concurrent procurement of logistics support and the acquisition of the aircraft, an attempt was made to break the logistic support effort into its simplest components. After many meetings with logisticians, maintenance personnel and operational Air Force organizations, the procurement team decided the effort could logically be broken down into six component parts. These components were: (a) a preoperational period, (b) initial lay in of spare parts and support equipment, (c) the mobilization effort necessary to activate the MOB(s), (d) flight hour component, (e) the fixed cost of operating and maintaining the MOB(s), and (f) a catch all area referred to as over and above.

The preoperational period was defined as the period of time from contract award date until the delivery of the first operational aircraft (approximately 33 months). The effort required of the contractor during this period is seen as a planning and coordinating task. Specific examples of tasks that will be performed during this phase of the contract are developing an Integrated Support Plan, performing an analysis and review of KC-10 support equipment requirements, performing an in-depth study of materiel handling equipment requirements, evaluating the effect of proposed aircraft configuration changes on the supportability of the KC-10, provisioning of both aircraft and support equipment spare parts, and defining specific maintenance tasks that will have to be performed.

The investment material component is comprised of all spare parts, support equipment and any other materials that are needed to support the aircraft. Materiel required to provide for replenishment, obsolescence, etc., is specifically excluded from the initial investment component. Because the KC-10 was expected to have a high degree of commonality with commercial versions of the aircraft chosen, it was expected that the logistics support contractor would be able to use existing commercial inventories to provide a portion of the investment materiel required. Accordingly, the offerors were given the latitude to commingling materiel specifically purchased for the KC-10 effort with existing inventories. The contractor will stock investment materiel to support our operational requirements and use the commercial base as the situation dictates.

The MOB activation component is comprised of the nonrecurring effort necessary to activate the contractor's operations at the MOB(s). The efforts include moving employees to the MOB site, providing the necessary communications, furnishings, shelving and warehouse material handling equipment.

The flight hour component encompasses the labor effort and material necessary to operate the aircraft on a daily basis. In performance of this effort, the contractor provides replenishment spares, spares maintenance, periodic aircraft inspections and the maintenance effort for all support equipment, except that drawn from USAF inventories. The costs associated with this effort are a function of aircraft flying hours. Accordingly, this effort is seen as the variable cost per flight hour portion of the maintenance effort.

The fifth category of effort consists of all fixed cost activities necessary to maintain and operate the contractor's activities at the MOB. This effort consists of such activities as providing supply and clerical personnel necessary to manage the spare parts operation, providing contractor field service representative to act as advisors to the Air Force performed on aircraft maintenance effort, and providing the housekeeping supplies and services necessary to operate the MOB.

A sixth, unpriced area called "over and above" was added to the contract. This category includes all work required by the contractor but not included in the previous five categories. This category is seen as emergency or special contingency type work. The prices and performance periods for over and above work will be negotiated at a time when specific over and above work is identified. Over and above work includes such things as

field team crash damage repair, unscheduled heavy maintenance, aircraft modifications resulting from service bulletins or engineering change proposals after the aircraft are placed in service and flying hours in excess of those provided for in the flying hour component of the contract.

In order to contractually accommodate this breakdown of the effort required, the logistics support contract made liberal use of recurring options. The basic contract served as the procurement vehicle for the preoperational phase effort, an unpriced line item was incorporated to provide the over and above capability and four options were established to provide the capability to procure the remainder of the effort.

The option to provide the returnable investment material is a recurring option. It consists of a matrix of ceiling prices which allow the Air Force to procure returnable investment material for 1 to 16 aircraft at from 1 to 3 MOBs. The Air Force has freedom to control both the number of aircraft and the number of MOBs. There is no requirement to completely fill one MOB with 16 aircraft before activating another MOB.

It is stressed that the matrix is composed of ceiling prices. The matrix contained in the contract appears below:

CUMULATIVE CEILING PRICES IN BASE YEAR DOLLARS ($ in Millions)

Total KC-10 Supported at Each MOB	MOB No. 1	MOB No. 2	MOB No. 3
1	$12.7	$10.6	$10.3
2	14.1	11.2	11.0
3	15.3	12.0	12.0
4	17.2	13.8	12.8
5	21.1	17.8	16.5
6	22.5	18.8	17.8
7	25.1	20.5	19.6
8	26.2	21.5	20.6
9	30.3	26.1	25.1
10	31.4	27.2	26.2
11	32.1	28.5	26.9
12	32.8	29.5	27.9
13	34.2	30.9	29.7
14	41.8	35.3	34.0
15	42.5	36.0	34.7
16	43.3	36.8	35.5

This matrix operates as follows. Suppose that the Air Force has a projected KC-10 fleet of three aircraft. For the first year, Option one would be exercised for three aircraft, with a ceiling price of 15.3 million dollars. Upon option exercise, the contractor begins his provisioning process and determines the kinds and quantities of returnable investment material required to support three aircraft. The contractor then compiles a priced listing of the required material and submits the listing to the Air Force for review. The Air Force then reviews the listing for the purpose of determining if some listed items may be available from existing Air Force inventories. If items are available, then the Air Force can remove them from the listing submitted by the contractor and provide Government equipment to perform the required tasks. In the event of such substitution, the ceiling price is reduced by an amount equal to the corresponding amount on the priced listing originally submitted. The contractor is then paid for equipment purchased as it is delivered up to the ceiling price amount. The contractor is required to provide investment material in sufficient quantities to support a 1200 hour per year flying program for each aircraft. If the provisioning model used by the contractor does not provide investment material adequate to meet the performance parameters set forth in the contract, the contractor is obligated to procure additional investment material. Should this be necessary, however, the contract price will only be increased to the ceiling price. Any material required after the ceiling price has been reached must be provided at contractor expense.

If, at some time in the future, the KC-10 force size would be increased to 10 aircraft, the option ceiling price would be increased to 31.4 million. At this point, the contractor would start the process over by submitting a proposed list of equipment to be purchased with the additional 16.1 million dollars to support the 7 additional aircraft.

Contractual coverage for the site activation, flying hour program, and MOB operation portions of the logistics support effort was also provided through the use of options. Option 2 for site activation is exercised once for each MOB on a fixed price basis. Option 3 (flying hour program) and Option 4 (MOB operation) are exercised on a recurring fiscal year basis. Option 3 prices are fixed prices on a flying hour dependent matrix and Option 4 prices are fixed prices on an airplane per MOB dependent matrix.

The requirement for an exercise of Options 3 and 4 each fiscal year places a requirement on the Air Force to take positive action each year in order to continue the effort under this contract. In the absence of this

positive action, the contract simply expires, all returnable investment material procured through Option 1 is retained by the Air Force, and no termination liability is incurred by the Government. The end result is a contract with built-in flexibility to allow the Air Force wide latitude in the area of contractor logistics support.

The use of contractor logistics support results in a significant reduction of facilities' investment cost to the Air Force. These savings were realized because the logistics support contractor chose not to invest in any new repair or maintenance facilities, but to use existing excess capacity in the hands of the commercial airlines. Although no single airline has reserve capacity great enough to handle all of the KC-10 requirements, the total of this excess capacity is more than adequate to meet the KC-10's needs. The logistics support contractor is able to take advantage of this excess capacity by the use of extensive subcontracting.

When a part or defective item of support equipment is turned over to the logistics support contractor, he turns it over to a commercial FAA certified repair facility. The details of accomplishment such as modifications, improvements or configuration standards will be managed by the contractor. The repair agency will be tasked with providing all the effort required to complete the repair. There will be no exchange of components at the repair facility. The same part will be returned to the logistic support contractor upon completion of the repair. This feature assures that KC-10 components will all retain the same configuration status.

Another savings advantage accrues to the Air Force in the area of provisioning. At the time of KC-10 provisioning, a cumulation of data compiled over three and one half million flying hours of commercial DC-10 will have been amassed. Employment of a contractor originated computer program utilizing Mean Time Between Failure (MTBF), removal rates, flight frequency, minimum protection level, aircraft utilization, repair turn-around time, and procurement lead time help to insure that only the minimum number of spares required to do the job will be purchased.

Compounding this savings is the advantage gained by not having to procure high dollar low usage spare parts (Insurance Spares). Insurance items are always expensive and are usually not actually used. They are generally procured and stored in a warehouse. If they are used, it is generally only for the period of time that it takes to repair the damaged unit. If and when there is a need for such items on the KC-10, we will be able to rent an item for the period of time it takes to get the damaged item repaired from the logistic support contractor's inventory of such items that is maintained in support of the commercial users of the DC-10.

Because the contractors were asked to quote firm or redeterminable price arrangements for logistics support extending to September of 1984, it was felt that the contractors would build in an excessive hedge against inflation unless an economic price adjustment provision was included in the contract. Since the pre-operational support effort called for by the basic contract will be completed in October 1980, we didn't feel the risk of inflation on the cost of this effort would be too great for the contractor to assume. For this reason, the economic price adjustment clause negotiated and included in the contract is applicable to the Option provisions only.

The economic price adjustment clause included in the logistics support contract adjusts the Option prices in accordance with the movements of the Department of Labor Index of Employment and Earnings, SIC 3721, and the Wholesale Price and Price Index for industrial commodities. For Option 1, which contains a great many spare aircraft parts, the movements of the metal and metal products classification of the Wholesale Price and Price Index have also been factored into the economic price adjustment formula During the proposal evaluation the movements of these indexes were gathered for the last ten years and were analyzed for any indication of abnormal movement. This analysis revealed that the indexes acted as a reasonable predictor of actual economic conditions and that no significant advantage would have been gained by the contractor over this period of time if an agreement identical to the contractual economic price adjustment provision had been in effect.

In the operational aspect of this contract, the contractor has been given physical control over the resources required to support the KC-10. This may not sound like a great achievement, but it is in the area that a tremendous "hidden savings" can be realized by the Government. By placing the property under the control of the contractor and by not entering the purchased equipment into the Government property control system until such time as the contractor logistics support is discontinued, the Air Force relieves itself of a gigantic record keeping task and the associated overhead costs that go with it. Problems of inventory control, configuration management, procurement of small lot sizes, product shelf life, pilferage, etc., are now problems that must be handled by the contractor. Although the costs for these functions must, by necessity, be included in the contract price, the logistics support contractor is working with a specialized system designed for the task at hand. This

specialized system allows the contractor to manage and control valuable resources in a very efficient manner that is not obtainable in the large cumbersome omnibus system established for the control of Government inventories.

At the same time, the substitution capability in Option 1 allows the Air Force to take advantage of the Government supply system for those items that are currently in the Government inventory and are being efficiently managed by the Government system. As can be seen, the Air Force derives the best of both worlds in the area of resource management. Items which will be used on the KC-10 which are not readily available through the existing Government supply system will be controlled and managed by a small system custom designed for specific applications. Items required for logistics support of the KC-10 that have a broader application will be managed and controlled through the existing system allowing the Air Force to take advantage of the economies of scale inherent in a resource control system designed for large quantities of material and equipment.

SUMMARY

The KC-10 procurement is a unique attempt to convert a commercially proven aircraft into an advanced strategic weapon system and provide contractor logistics support. These innovations, such as simultaneous award of acquisition and logistics support, the Green Line, and the Unit Price Matrix, combined with the inherent flexibility provided by the contracts, permit the Government to take advantage of Douglas' commercial structure and system while remaining within the confines of acceptable Government procurement practices.

This procurement avoids the expense of development costs for a program with a great deal of commonality with a commercial program. It further emphasizes an early consideration of total program costs by the simultaneous award of the logistics support contract. This had the dual benefit of forcing early consideration of support costs in the acquisition, and working in a more competitive environment for the logistics support contract itself.

Finally, and most important, the Government is acquiring a greatly improved capability at a reasonable cost by using procurement techniques which provide the flexibility to best satisfy the Government's needs.

PROGRAM MANAGEMENT

MISSION MANAGEMENT: THE KEY RESPONSIBILITY OF PROJECT MANAGERS

Robert Judson, Sterling Institute
(Former Executive Director, Navy Center for Acquisition Research)

EXECUTIVE SUMMARY

This research suggests the critical decisions that must be controlled to assure a successful major systems acquisition. The research was based on an evaluation of the revised statutes, policies and regulations dealing with major systems, including OMB Circular A-109, DOD's revised 5000 series, and counterpart changes in statutes dealing with budget presentation.

Research suggests a clear opportunity to protect the integrity of major system acquisitions by the timely introduction of project management into critical "front-end" decision-making, i.e., mission management.

Past studies dealing with major system acquisitions have suggested that a project manager inherited critical problems based on early decisions related to requirements determination. Often it was too late for a project manager to eliminate or significantly modify these problems. In such circumstances, the problems loomed as dominant characteristics affecting the success of major systems.

This research suggests that the project manager should be a vital contributor to early decision-making which can be designed to avoid or mitigate the typical project management problems of schedule slippage, performance shortfall and cost growth.

Specific guidance for a project manager and specific actions that can be taken in terms of mission management to assure the success of a program must be set forth as the basis for "problem avoidance" decision-making.

A unique concept of staffing early project management responsibilities is suggested to cover key new responsibilities in project management, at Milestone-0, "Program Initiation." This concept proposes a mission management team whose responsibilities embrace an entire mission area as the best assurance for consistent decisions on individual mission elements.

Practical problems of complying with revised policies, including budget-related issues, must be addressed. Changed requirements are summarized along with potential pitfalls in complying with new policies and ways to cope with the full range of new project manager responsibilities.

A basic illustration, manpower and training needs, is utilized throughout this study.

MANPOWER CONSIDERATIONS

Manpower considerations, like other key concerns in weapon system procurements, have suffered in the past because of the requirements determination process. A premature lock-in to a single system answer to meet assumed needs also locked in manpower costs and resources. This was not the result of a rational decision-making process but often done by default. Cost and resource characteristics are implicit in early preconceived specifications of a system. Frequently the results of this premature lock-in could not be appreciated until years later when it was too late to modify basic systems decisions to consider adverse manpower or other impacts (e.g., maintainability, reliability, operability, etc.).

Two basic problems are involved. First is the lack of an explicit recognition of manpower and training implications in early systems decisions. The determination, identification and program establishment for manpower resources typically have not occurred until late in hardware development. There is no assurance that services will have the number of qualified personnel to meet operational requirements on a timely basis for systems that are produced under such a requirements determination process.

A second and most important problem is that manpower considerations have been responsive to, rather than determinative of, equipment designs.

We have been able for a long time to recognize the implication of manpower costs and the reduction in the size of the labor force as constituting issues of crisis proportion in terms of affordability and availability of major systems. What we have not been able to do is link these "crisis issues" to incorporation in an acquisition strategy that would permit us to address manpower considerations in a logical and timely manner and minimize the adverse characteristics of the manpower crisis.

DETERMINING MANPOWER REQUIREMENTS

There are two key levels of consideration relating to the determination of manpower requirements. The first might be designated as a "general" concern with basic manpower standards and profiles of the type of operating personnel that a Service can expect to have generally available to operate equipment in the future. This sort of idealized profile should become an important design parameter to be traded off against other design considerations. In the past we have never had such explicit design concerns and hence manpower considerations were simply those that "fell out" from the design that was finally produced.

A second level of manpower concerns has to do with a specific equipment design. For these two levels of concern we need a manpower information system which suggests: (1 general design considerations (what standard profiles of personnel might be) 2) detailed manpower information which derives from the specifics of a given system.

This is not a proposal to do one or the other, it is an admonition to do both. The first protects the integrity of the second.

MANPOWER STUDY

The recent Navy manpower vs. hardware study makes a great point about the absence of timely manpower considerations in past acquisitions. The study does not adequately identify the reasons for this. The lack of opportunity because of the late timing of manpower considerations, and because of the design turbulence which characterizes decision-making in major systems, upset any chance for orderly consideration of manpower requirements. No matter how sensitive an information system is built, unless there is a timely and solid design base for the application of the system, the information system is meaningless. No matter how highly motivated the Services are to consider manpower needs, the Services will not have success unless the equipment design evolution is on an orderly basis and incorporates the general parameters of manpower profile considerations for the purposes of making basic design tradeoffs.

The Services do not lack for the talent to anticipate, identify and model manpower and training requirements as much as they lack the opportunity for this talent to make a timely contribution against a firm design base.

REVISED SYSTEM

Under the revised system of decision-making inherent in OMB Circular A-109 and DOD's 5000 series revisions, considerations for manpower and training requirements should be an integral part of an acquisition strategy. Moreover, manpower representatives should be involved in the mission area analysis so that the general standards and concerns for manpower and training needs would condition the search to be performed by the private sector through the technology base for conceptual or design alternatives. This is an argument for a more aggressive use of our manpower experience in conditioning early decisions which determine what the manpower and training requirements are anyway. This is an argument for addressing manpower considerations in early designs in the search for competitive system alternatives.

THE FUNCTIONAL MANAGER AND THE PROGRAM MATRIX

Lieutenant Colonel Martin D. Martin, Air Force Logistics Command

INTRODUCTION

In an environment of declining resource availability, program management has been advocated as a technique which can be of assistance in obtaining better resource utilization. Program management as contrasted with functional management will in this paper be considered as synonomous with project and product management, even though a case can be made for definitional differentials. For each, the ultimate objective is the development and production of an item to satisfy a specific operational requirement.

BACKGROUND

In the Department of Defense (DOD) the end result is generally the production of a specific weapon system for introduction into the operational inventory. With the functional organization structure (See Figure 1), each program would be the responsibility of each functional manager in terms of accomplishing a given function, such as procurement or manufacturing. The difficulties of using this type of organizational structure for weapon system acquisition are many. The difficulties are reflected in Table 1 as advantages for program management and vice versa.

TABLE 1

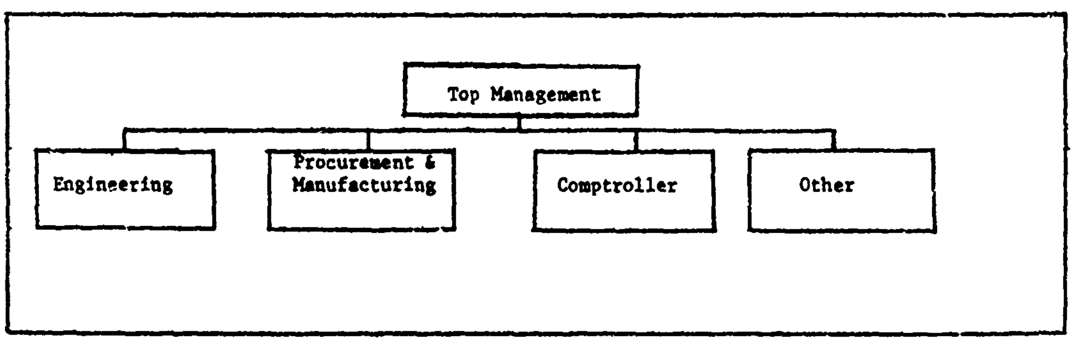
ADVANTAGES AND DISADVANTAGES OF PROGRAM MANAGEMENT AS AN ORGANIZATIONAL STRUCTURE

Advantages

- Planning is facilitated by using Program Evaluation Review Techniques (PERT), Critical Path Method (CPM), etc.
- Financial Control is improved.
- Organizational flexibility is enhanced.
- Better integration of system components is possible.
- More flexibility for trade-offs between system parameters.
- Higher visibility for problem identification and correction.
- Resource accountability is improved.
- Leverage for subordinate cooperation and motivation.
- Independence to resist unwarranted change (gold plating).
- Independence to facilitate change, when warranted.
- More efficient use of specialized personnel.
- Provides continuity, stability and consistency for the accomplishment of the assigned mission.
- Provides a life-cycle cost horizon for planning.
- Appeal mechanism through accessibility to top management.

FIGURE 1

REPRESENTATIVE FUNCTIONAL ORGANIZATION



Facilitates and improves communication.
Provides managerial training to cover management succession.
Fosters a spirit of competition for better resource use.
Permits management focus for mission completion.

Disadvantages

Requires high level of coordination between the Program Manager and other functions.
People can become too committed to the program.
Specialization gives narrow perspective - can have a problem of obsolete technical skills.
Creates high potential for organizational conflict.
Dedication of resources to specialized task gives resource inflexibility.
Introduces complexity into the overall organization.
Tendency is for the program to become a permanent organization.

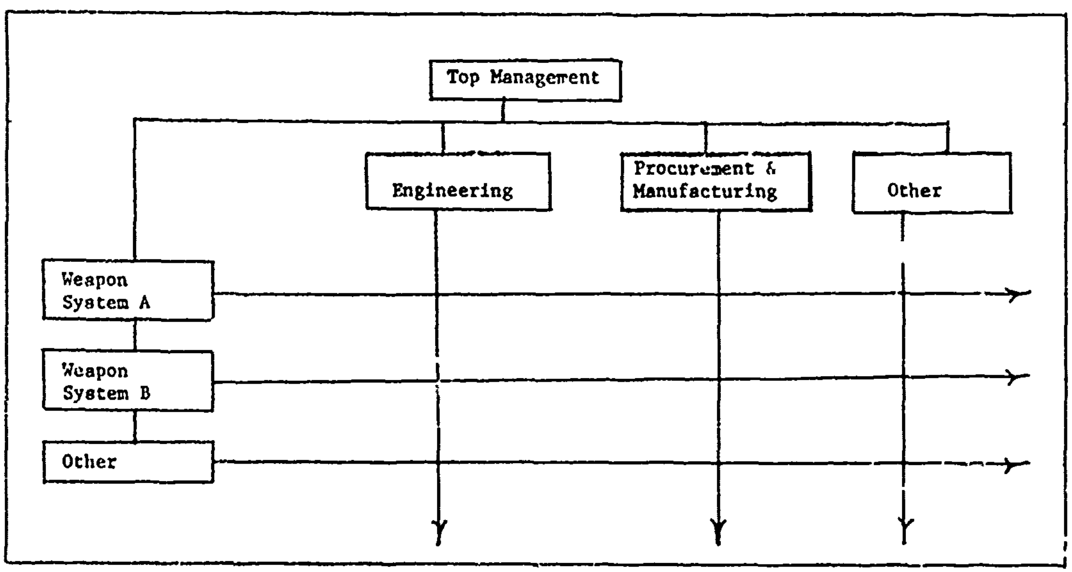
Thus, the three product divisions in the Air Force Systems Command are established organizationally in a specific system program office (SPO) configuration. At the Aeronautical System Division (ASD), the matrix structure has been adopted. (See Figure 2).

Several variations for program management; i.e., matrix, projectized, etc., depending on your frame of reference, as contrasted with the overall organization exist at ASD. For example, the Deputy for Propulsion has been established to manage engine acquisition. The organization operates in a multidimensional matrix comprised of the ASD functional staffs, such as procurement and manufacturing, the airframe system program offices, such as the F-15, F-16, and the A-10, and the engine manufacturers, such as General Electric, Williams Research Corporation, Fairchild Republic and Pratt and Whitney.

The organizational problem arises in the conceptual phase of the weapon acquisition process. A SPO cadre is selected. The Program Manager assisted by this staff and the ASD functional staffs, then organizes and staffs the program office. Personnel from the functional areas of procurement, manufacturing, engineering, etc., are colocated with the program office on an as required and later as validated by a workload assessment study basis. Research indicates that competition for manpower resources is greatest in this phase (1). From the standpoint of the overall organization (ASD), the main value of this structure is the mobility and utilization of manpower resources which can theoretically be shifted to meet mission requirements. The purpose of this paper is to examine the role of the functional manager,

FIGURE 2

REPRESENTATIVE MATRIX ORGANIZATION



specifically, the procurement and manufacturing manager, in this matrix organization.

EXPERIENTIAL ANALYSIS

The anlysis of the procurement and manufacturing manager's (hereafter referred to as the procurement manager) role will be conducted using pertinent factors from Table 1. These advantages were developed as related to the perspective of the program manager, however, many of them should accrue to the procurement manager, as the specialist who manages a specific area for the program manager.

Planning as envisioned for the program manager is not in the decision realm of the procurement manager. The planning responsibilities of the procurement manager primarily lie in the areas of procurement planning (6). These plans include type-of-contract to be used, negotiation strategy and tactics, cost considerations, delivery quantities and schedules, quality requirements, and other business matters. If the procurement manager does not have to obtain detailed guidance from the home functional staff, then the planning function is not affected too much by the matrix.

Financial control in the SPO is primarily the responsibility of the program control activity. In this respect the procurement manager is required to coordinate financial matters with the program control activity. These same types of checks and balances exist under the functional organizational format and are a necessity for the maintenance of the integrity of the fiscal system.

The organization of the procurement activity is generally controlled in detail by the home-office functional staff. The number of officers and civilians in the various grades are limited. Organization structure and staffing have an impact on the grades of both supervisors and workers. Consequently, if changes are made in one part of the functional matrix system, such as an upgrading, then basically, reductions, within limits, must be made in some other SPO. Thus, the flexibility principle is negated. Organizational changes most often occur with changes in mission and the associated workload, rather than based on a management decision by the procurement manager. Organizational structures once established seem to persist over time. Change when it does occur is initiated at top management levels.

From the standpoint of the overall organization, the program matrix supposedly facilitates resource utilization based on the concept of mobility. The home-office functional manager is able to shift resources in the matrix by rescinding a colocation assignment and issuing a new letter assigning a specific resource to a different location. However, the system does not work in this manner. The colocated functional manager does not like to see his resources diminished by reassignments. He is aware of the difficulty in obtaining manpower resources, and is consequently not willing to release them, since, after all, his workload may increase and then where will he get people to do the job. Also, the release of manpower resources may well affect the grades of the people who work for him and possibly his own grade, thus a flexible system becomes rigid and inflexible. Each organization must now be subjected to a manpower assessment review in order to free resources and in this situation, elements of power and negotiation will often determine the ultimate allocation of resources. The program matrix has, in other words, assumed the nature of a bureaucracy and no longer fosters those concepts which gave it birth. The bureaucratic rigidity seems most intense during the validation, full scale development and production phases (1).

In theory, the procurement manager should benefit from increased communication through the matrix system. However, he finds that his loyalty is in question by both the program manager and the home-office functional manager. If he communicates details of plans which the program manager has made, he may find that his functional supervisor possibly is not in favor of the contemplated course of action. The functional staff takes action to block the program manager. Thus, in some cases, thwarted, the program manager wants to know why the procurement manager relayed the information to his functional supervisor. This situation may occur in reverse order. Assuming a defensive posture, the procurement manager is now in the position of selective information transmission. Thus, the free flow of ideas and information is restricted and sifted based on a careful analysis of the possible reactions of all the parties concerned.

The program matrix structure should focus the attention of the procurement manager on critical problems so as to enhance mission accomplishment. While this condition occurs in some cases, in many others, it does not. Rather, the procurement manager and his staff spend excessive time on coordination of letters, charts and other documents. These coordinations must generally involve the other functional activities of the SPO, in some cases other SPOs and the home-office functional staffs depending on the final destination and nature of the document being processed. Many documents are lost in the coordination process, and effort must be expended in trying to locate them and if not located, then in preparing them anew. Another activity which fragments the activities of the functional

manager is frequent and long meetings. Someone must attend to protect the interests of the procurement activity. In many cases the meetings are not well organized. For example, no one knows for sure why the meeting was called. As the meeting progresses, the actual reason, as compared to the stated purpose of the meeting becomes apparent. Little can be accomplished as no one has had an opportunity to do adequate staff work, however, no individual is willing to admit this and so the meeting drags on. At the end very little has been accomplished. A subsequent meeting is necessary to deal with the problem which caused all of the activity in the first place. The procurement manager can usually choose his meetings. His own personnel, the program manager, other functional activities and the home-office functional people are all scheduling meetings. Often several meetings are scheduled for the same time period. Naturally, the importance of the meeting precludes its being rescheduled, therefore, substitutes are dispatched and decisions made as to the relative importance of the various meetings. A wrong choice can put one in a disadvantageous position relative to the power hierarchy in the SPO and the matrix.

Conflict is an accepted characteristic of the program management environment. The condition arises from many activities, including the inevitable competition for resources, the selective communication transmissions and receipts of the procurement and other managers, the exponential coordination requirements, and the generally defensive posture assumed by many of the individuals on the program manager's staff. The key for the resolution and minimization of the conflict is for the respective managers to convert dysfunctional to functional conflict (1). The procurement manager must be aware of and accept the fact that conflict is natural to the program matrix. Then by judicious use of meetings and other actions which are carefully planned, he should use the problem-solving approach to make conflict work for him so that organizational goals can be attained.

The procurement manager has limited control over his resources and has difficulty in obtaining feedback from his people relative to the effectiveness of mission accomplishment. This situation derives from the relationship between the primary workers and the program manager. The scalar chain from the program manager through the procurement manager to the primary worker includes the reward and penalty system. This environmental given, as perceived by the primary worker, leads to the informal pledging of loyalty to the procurement manager and indirectly to the program manager, rather than to the home-office functional supervisor. This condition generally exists, even though the home-office functional manager does have some reward and penalty power by virtue of assignments, etc. Loyalty to the program manager is tempered by the fact that many individuals see him as a remote, inaccessible figure, whereas, they have more frequent contact with the procurement manager. The program manager, however, in his role as his people's representative, must spend much of his time looking at variables external to the SPO, thus, this alienation is to be expected. However, few program managers understand this situation and have taken aggressive action to correct it. As a result of the above factors, group cohesion usually does not develop as a consequence of managerial action, rather it develops in specific situations in response to other environmental variables. The procurement manager's control is further eroded by the influence of the home-office functional staff who often contact colocated personnel and issue operational and policy instructions without proper coordination with senior colocate functional managers. Feedback efforts are complicated by these same considerations and others. The functional manager wants to look good, performancewise, and to stay out of trouble. Consequently, there is often a tendency to play the program manager against the home-office functional manager and vice versa. In many cases, the result is conflict and degradation of mission accomplishment.

CONCLUSIONS

Where the program matrix organization structure is used, there appears to be a tendency for the involved organizations to become increasingly more and more bureaucratic. The procurement manager finds that the advantages of the program matrix are negated over time. Indeed, the studies analyzed by Adams and Barndt support this conclusion (1). These problems are not unique to procurement and manufacturing, but seem to occur relative to engineering, logistics, program control and other colocated functions. A difficulty encountered in this study effort was the lack of research which relates to the role of the colocated functional manager. As a result, much of the analysis is based on experiential observations and impressions. Most of the research in the area of the functional interface in program management relates to the role of the procuring contracting officer, the industrial specialist, and the program manager (2, 3, 4, 5, 7). For example, the authority grid surrounding the procuring contracting officer has been examined; his value system has been explored; and the program manager, his role, qualifications, etc., have been studied. The need is for in-depth studies of the colocated functional manager, specifically, what can he do to cope with resource and organizational inflexibility, excessive meetings and coordination requirements, dilution of control, and the resolution of conflict.

At present the majority of colocated functional managers are doing their jobs in an excellent and competent manner. However, this condition is occurring in spite of the program matrix, not as a consequence of its effectiveness. Certainly, many of these problems are also applicable to functional management and are not amenable to easy solutions, however, it is time for management to come to grips with the paralyzing influences of systematized bureaucracy, masquerading as a program matrix, and the researchers should conduct studies which will provide knowledge to assist in obtaining improved mission effectiveness and efficiency.

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THE SCOPE OF THE BUSINESS MANAGEMENT JOB IN DEFENSE PROGRAMS

Thomas Y. L. Dunlap, Hughes Aircraft Company

INTRODUCTION

Greater emphasis on business management of programs is evolving in recognition of industry's need for profit and return on investment in an evermore complex defense market. Design to Cost and Life Cycle Cost considerations, new initiatives in system acquisition policy resulting from OMB Circular A-109 and NATO Standardization and Interoperability requirements are current examples of how the market is changing. Industry must change too, to be more able to respond to DoD's needs for weapon systems performance within a more highly controlled cost, schedule and contractual environment.

This paper gives a new perspective on the extreme complexity of the defense business management job through a cross-sectional view of an industry business management training program. After three years developing this training program, we have been led to the conclusion that careful analysis, considered judgement, patience and understanding are, perhaps more than brilliant new policy measures, the basic requirements for improving the defense systems acquisition process.

The training program was initiated in response to needs expressed several years ago by program managers of Hughes Aircraft Groups. At that time a conference of more than forty program managers was held to share experiences on programs ranging in size from a few million dollars to over a billion, and in scope from advanced development to high rate production. During the conference, attention was focused on common problems and exchange of ideas for effective solutions. Better integration of the several business management functions essential to program management, and increased application of analytical skills in business management were perceived as growing steadily in importance. As a result, a broad scope of skills and activities has been defined that comprise the program business manager's job. A 270-hour training course has been established to cover this scope. Interfaces with technical management and the non-technical areas such as finance, procurement, contract negotiation and administration are emphasized in the course.

How the training course was developed and implemented, and concrete examples of the issues, activities, and information covered in the cource illustrate the scope of business management challenges now and in the future. More than sixty Hughes executives and managers have participated in preparing the course and giving instruction. Now, midway through the first class, experience is showing that an even broader scope of skills and subjects needs to be addressed. So now, join with me in entering the world of the Hughes Aircraft Company's Aerospace Groups, to look at a program whose purpose is to cope with the very complex acquisition management process.

THE BUSINESS MANAGEMENT DEVELOPMENT PROGRAM

The world of the Hughes' Aerospace Groups is familiar to many of you: the world of the Phoenix, Maverick and TOW missiles, the AWG-9 Weapon Control System, the APG-63 and APG-65 radars, and many other electronic and electro-optical defense systems and subsystems. It is the world of exploratory and advanced development, full-scale development, production and integrated logistics support. Most surely, today it is the world of mission need analysis and alternate concept development with a heavy emphasis on NATO standardization and interoperability. In short, your world, our world of defense systems acquisition.

You are an industry program manager. You are responsible for the complete technical, cost and schedule performance of your program, including bottom line contract earnings delivered to your corporation.

As a means to improve program management within your corporation, you are invited to attend an off-site conference to talk over program management problems with forty of your peers. In two days of discussions you have renewed your perception of the steadily growing complexity of the defense business management job. You agree with your colleagues, some of whom have business managers in their program offices, that you too, could use a right-hand man for business management. Someone to provide better analysis and integration of functions such as program planning and control, contract administration, material procurement and control, finance, data management and administration.

From this kind of thinking came an action item from Hughes Aerospace Groups executives: Initiate a program to accelerate the development of business managers for assignment to major program offices. This action item was assigned to an ad hoc Executive Council consisting of three major program managers, a group controller, director of contr...r, and director of materiel. The Executive Council has four jobs:

1. Develop course data
2. Select candidates

3. Provide qualified instructors
4. Coach trainees

The Council is supported by a program administrator from the Management Systems staff and a program consultant from the Management Development staff.

The process of developing the course data has served to outline the extremely broad and complicated defense systems acquisition management job. The course content is a true reflection of the complexity of the management challenge for both industry and government in working with the defense systems procurement and acquisition system today.

CURRICULUM

The term "course data" quickly converted to "curriculum" as the Executive Council turned professionally to its first task. An early indication of the scope of the task came with selection of the core subjects to be covered. Sixteen subjects were finally selected with the course limited to 270 hours. The course is conducted over a nine-month period, 20% after hours and 80% during working hours. The sixteen chosen topics are:

	Subject	Total Hours
1.	Manufacturing	34.2
2.	Management Concepts & Techniques	32.0
3.	Contracts	21.4
4.	Program Control.	20.0
5.	Written Communications	20.0
6.	Materiel	18.4
7.	Finance	18.2
8.	Oral Presentations	17.5
9.	Engineering	16.1
10.	Proposal Preparation & Source Selection	16.0
11.	Cost Estimating & Cost Analysis	15.4
12.	Team Building	10.0
13.	Systems Support	9.6
14.	Group Executive Sessions	8.0
15.	Design to Cost & Value Engineering	7.2
16.	Data Management	6.0
		270.0

To illustrate the breadth of the course, the outline of one of the sixteen core subjects is shown below.

PROGRAM BUSINESS MANAGEMENT DEVELOPMENT CONTRACTS - COURSE OUTLINE

Session No.		Speaker/Guest
25	Course Introduction	C. W. Lefever C. F. vonLunenschloss
26	The Customer's Acquisition Cycle	J. F. Drake J. V. Ferrero, Jr.
27	The Request for Proposal	L. A. Enstedt D. R. Capps
28	The 897 (Hughes' Proposal Kick-off Form)	J. P. Kopley
29	Pricing the Effort	L. A. Buckley J. R. Rohlinger H. Siegel
30	Negotiation of the Contract	J. H. Leimert G. D. Howland L. E. Molnar
31	Legal Issues of the Contract	R. P. Wiley C. S. Haughey J. K. Haskell
32	Management of the Program	S. J. Brookins J. R. Giacoletto M. P. Lawton
33	Contracting for Logistics & Support Services	D. L. Cassidy
	Contract Terminations & Closures	H. R. Cranston C. F. Eason
34	Wrap-Up	C. W. Lefever

Outlines of topics covered in each of the other fifteen course segments are equally as extensive. In addition, a formal syllabus has been developed covering the objective, content and teaching methods for each subject. However, this paper is necessarily limited to some observations of interest and examples highlighting complexities, paradoxes and difficult trade-offs that have become evident.

First, some observations from your viewpoint as a program manager. The subjects listed above clearly show that your business manager must be broadly grounded and able to understand, analyze and integrate many different functions and skills. He is essentially a program manager in every respect, except for the requirement to give technical direction. Many times the industry or service program manager is likened to a general manager or commanding officer. The business manager is clearly a close deputy - almost in your image. In other words, he is highly skilled and critically important to the success of your program.

Notice the emphasis given in the course curriculum to communication skills. Ten hours on Oral Presentations, twenty hours on Written Communications, plus additional hours within the Team Building, Management Concepts and Techniques, and the Proposal Preparation and Source Selection segments. Communication is the essence of management and as such is featured throughout the course. <u>This is an important perspective for all of us in industry and government</u>.

You may notice that Manufacturing is allotted twice the time allocated to Engineering. On the one hand there is necessarily a very strong dependence on management systems in dealing with manufacturing. On the other hand, there is usually a strong system engineering branch in most program management organizations which contributes greatly to the orderly management of engineering activity. In addition, most of our program managers have an engineering background. Accordingly, we have placed great emphasis on the interface between Manufacturing and Engineering.

The shorter time allotted to Systems Support does not indicate lack of emphasis of Integrated Logistics Support (ILS) nor of design for Reliability, Maintainability and Low Life Cycle Cost. (All subjects that need to be well understood by anyone seriously proposing improvements in the acquisition process.) Rather, this reflects that within Hughes Aerospace Groups, support functions are managed in a fully integrated Support Systems Division which performs ILS program management and business management tasks as delegated by the program manager. ILS factors, of course, are also covered within the Cost Analysis, Design to Cost, Engineering and Manufacturing segments of the course.

A final important observation pertains to the selection of the instructors for each subject. Top management support of the program has been such that outside experts and professional educators could have been brought aboard to develop and conduct a professional educational program. However, the Executive Council chose to call upon others like themselves - experienced, effective, extremely busy executives and managers - in order to expose the trainees to the real people in the real world, as well as to train them in the subject matter. For example, the Contracts section outlined above is led by the Associate Director of Contracts for a 7,000-member operating group. Every speaker and guest listed holds a responsible management position at Hughes.

This has an analogy in the overall defense acquisition environment, related to the "belt way bandits," "congressional staffers" and elected or appointed officials. These are well-meaning people but they often impatiently overlook the wealth of experience and knowledge of industry, service and DoD career personnel. They sometimes turn to easy answers and miss the invaluable lessons learned by the career managers on the firing line. It is possible that some of our instructors may not be too professional in their teaching techniques. But the moral for the trainee is, it will pay you handsomely to extend yourself to learn from them. Now, for us to try to learn from them too, let us look at some of the more difficult subject matter brought out in our course.

CPT

CPT: "Complexities, Paradoxes and Trade-offs." No paper on the defense business should fail to use a new acronym! ("CPT was chosen because Oddities, Frailties and Procurement Peculiarities" has already been taken.) In this concluding section, I have browsed through the five-foot high stack of illustrations, expository charts, narratives, regulations, specifications, and standards given to the Program Business Manager Development trainees, and extracted a small sample of the knotty problems we all must deal with in the acquisition process. This is not a complete compilation of research information, but examples of the gold one can mine from the data bank this course has caused us to put together. If I have left out a problem of your own, I apologize. In the interest of time and space, let us proceed rapidly through these items in shotgun fashion:

<u>Make or Buy-1</u>: Industry and Service managers are advised to always use available capabilities which are better than their own (but don't give away the Company - or agency.)

<u>Make or Buy-2</u>: In subcontracting work out. Industry must make the absolute best buys (but

use minority, female and small business enterprises and use sources in labor surplus areas to the fullest).

Personnel-1: See Make or Buy-2 above. Add veterans and handicapped.

Personnel-1A: Each government program manager demands: "Put your best people on my program!"

Design: Value Engineering is truly effective in reducing costs...some say by doing over what you did wrong the first time. One of our customers has saved over $70 million via VECP's. In contrast, another uses VECP's if at all, to try to negotiate future prices down.

Design to Cost: Iterate the design several times (but do not increase the engineering budget).

Finance: Comply with Cost Accounting Standards (but do not increase administrative staff or cost).

A-109: Take all the time you need in source selection (but select the right horse in the beginning - maybe even a Belgian - and get him out on the track and running in less time than before).

NATO RSI-1: Improve other countries' economies at the expense of our own. (This can be a double whammy. Within Germany, for example, production of six identical new frigates is spread through five different shipyards to benefit five local economies.)

NATO RSI-2: Procure potentially less effective defense systems and equipment yet be fully responsible for the national defense. (Many are sworn to this responsibility.)

NATO RSI-3: The government is responsible for implementing standardization and interoperability (but should accomplish it through industry competition with minimum control).

Production Engineering-1: You must motivate your best designers to solve your production line problems (but you must not let them make any unnecessary design improvements. In other words, do "fool with human nature").

Production Engineering-2: You must motivate manufacturing to incorporate critical changes in the production line as early as possible (but you must not allow the schedule to slip or budget to overrun).

Cost: Even though your total cost is competitive, your 1) G&A, 2) overhead, or 3) labor rate is judged too high.

Life Cycle Costs: Plan and control Life Cycle Costs without the benefit of actual program cost visibility during the operational phase.

Materiel: Keep your vendors making those small lots of special parts for a few more years, even if no one else buys them any more.

Organization-1: Each government program manager demands: "Your program manager on my program must report to the Company President."

Organization-2: "Your Quality Assurance manager on my program must report to the Company President."

Organization-3: You need a fully projectized organization to get the job done (but you also need strong functional organizations to be able to employ and deploy the key functional specialists economically).

Management-1: Don't ask for help needlessly (but never surprise your boss with a problem that's beyond you).

Management-2: Always use contractors with solid records of proven performance (but prolong, extend, promote, expand competition).

Management-3: Focus on the important thing like major cost drivers (but withstand audits at the detail cost level).

Government Management: Achieve long term stability and efficiency (with incremental funding by annual appropriations and authorizations).

People in the defense acquisition business have to wrestle with such complexities, seeming paradoxes and trade-offs as the preceding twenty-four items continuously. The problems are not facetious, but real. They exist and must be dealt with honestly. They are difficult and typify what constitutes the heart of the Hughes business management development course...and this complicated business we are all striving to improve.

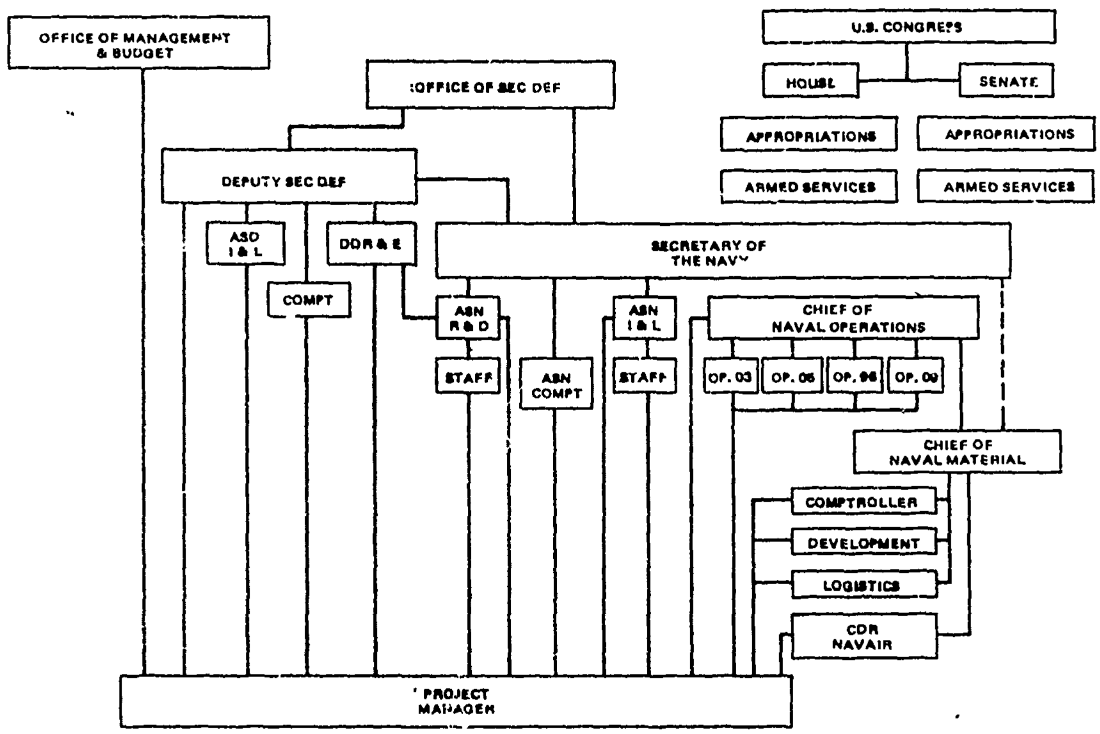
CONCLUSION

The intent of this paper has been to give a new perspective on the extreme complexity of the defense business management job by analogy: A cross-section view of one defense contractor's business management development program. Much has been left out: Not only topics and problems, but tools of the trade like the standard Glossary of Acronyms and Abbreviations (hundreds, thousands); an index of specifications and standards (for what specific area?); the

table of rules and regulations (which service, please!).

How about the complexity of our organizations, illustrated by this typical chart:

MAJOR MISSILE PROGRAM

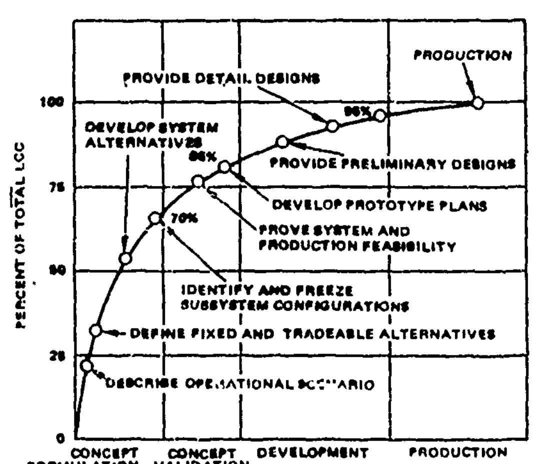


And this classic chart, here illustrating a point about life cycle cost, but, like Pareto's principle, a part of our business in every area: The biggest decisions must often be made when we have the least information.

A corollary to this is: We have to learn to live with a lot of problems and try very hard to make a lot of small improvements.

There are many reasons to be impatient with the defense acquisition process, the time it takes to effect improvement, the loss in translation from top-level policy to bottom-level practice ...and back. It is only natural that we sometimes say "Off with the old!"...Contract Definition?...and "On with the new"...Prototyping? ...but in point of fact, viewing the very broad scope of the defense business manager's job, and the myriad problems which must be faced, it must be concluded that careful analysis, considered judgement, patience and understanding are the watchwords for improving the defense acquisition process in any substantial, effective manner.

LIFE CYCLE COST COMMITMENT



ACHIEVING EFFECTIVE ACQUISITION THROUGH ORGANIZATION DESIGN AND LEADERSHIP INTERVENTION

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INTRODUCTION

In the development of need stage, the acquisition process is simple as profiled by organizational variables such as size of group involved, workflow among groups, spatial proximity of members involved, and the complexity of the task. The size is limited to those individuals establishing the need, the workflow is independent as the individuals have a defined autonomous task, individuals involved in the initial stage typically are proximate to each other through the process of regularly scheduled meetings and the task that is performed is relatively simple as the procedure is spelled out and there is available help in performing the task.

Once the decision is made to explore alternatives a program manager is selected who is responsible for recruiting a team with the requisite skills and experience to manage the acquisition. The acquisition process now begins to increase in complexity. Size of the group involved increases, workflow becomes more interdependent, tasks become more complex as the acquisition process moves toward the soliciting of competetive bids, and members of the acquisition team become more spatially dispersed. As the process moves through the stages of exploration of alternatives, competitive demonstrations, testing and evaluation, production, deployment and operation and goal analysis, the problems of coordination and control increase. Workflow becomes increasingly complex as more operations have to be interfaced. The task becomes more unprogrammed as the project moves into areas where no previous experience exists. Individuals of the team become geographically dispersed. As each of these dimensions of the organization becomes more complex, they adversely affect the acquisition process in terms of increased stress, tension, and conflict upon and among the participants.

If the acquisition process is to be effective, it is necessary to adapt and adjust the organization to offset the dysfunctional effects of increased complexity. Two strategies are available to the program manager for adaptation to increased complexity. One strategy involves designing the managerial system of the acquisition team to deal with the increased problems of coordination and control. It is necessary for the managerial system to be restructured as the acquisition cycle becomes more complex. Standards and objectives must be clearly defined. Measuring instruments must be developed to determine if standards are being met. The communication system must be more formalized and the decision making process more centralized to achieve coordination and control. Activities must be regrouped to facilitate coordination. The managerial system, then, which consists of delegation of decision making, departmentalizing activities, establishing a formal communication system, and designing a control system of standards and rewards must be designed by the program manager to achieve an effective acquisition program.

A supplement to managerial system design is direct leadership intervention. As the acquisition process becomes increasingly complex, the program manager should assume a more directive style of leadership to achieve the necessary coordination and control. The use of leadership intervention requires that the program manager be continually involved in every stage of the cycle, but increasingly so as the project moves through the final stages.

The purpose of this research is to determine the influence of design and leadership on three levels of organization effectiveness; individual, intragroup and vertical intragroup. It is assumed there is a causal link between these types of effectiveness and measures of productivity and profitability. The conceptualization used follows the model proposed by A. Melcher [6]. Exceptions are the inclusion of an operational measure of the information system.

THE MODEL

The model (Figure 1) embraces a broad definition of design and identifies a set of structural factors and leadership styles that exert influence over individual, intragroup and intergroup effectiveness. The structural variables are of two types, contextual and managerial. Contextual structure consists of size, workflow, spatial physical barriers and task complexity. Managerial structure consists of the formal authority system, the control system and the information system. The formal authority system is measured by the degree of departmentation and delegation. The control system is measured by standards and reward-penalties and the information system is determined by communication networks and channel density. Each of these dimensions can assume a range of values; workflow, for example, can range from independent to inter-

dependent. An organization can be profiled as simple to complex depending on the profile generated from describing each of the structure variables. As the contextual variables move from simple to complex they influence the behavioral processes in the organization; for example, as workflow changes from independent to interdependent conflict and stress occur. The managerial system can mediate the effects of context if it moves toward complexity in a compensating manner. Seven dimensions of leadership measure the style cf the leader which ranges from democratic to directive. These include representation, interaction, participation, goals emphasis, direction, rule adherence and inducements. The leadership style can influence the effectiveness by interacting with the structural variables. Leadership is viewed as a mediating variable which can operate to increase the dysfunctional effects of structure or to, ideally, off-set these effects. The effectiveness dimensions of the model are divided into three levels: individual effectiveness measured by motivation, commitment and initiative; intragroup effectiveness measured by lateral relations within groups; and intragroup effectiveness measured by vertical relations of group members with supervisors.

The Organization is viewed as a system. The contextual factors contribute to dysfunctional processes as they move from simple to complex. These forces may be offset by changes in the managerial variables. If the managerial system is poorly designed it will add to the disintegration of the organization. Similarly leadership interacts with the structural factors to enhance or offset the negative influence on effectiveness.

FIGURE 1

STRUCTURE PROCESS MODEL

CONTEXTUAL STRUCTURE	SIMPLE	COMPLEX
1. Size	Small	Large
2. Workflow	Independent	Interdependent
3. Spatial Barriers	Concentrated	Dispersed
4. Task Complexity	Programmed	Unprogrammed
MANAGERIAL STRUCTURE		
1. Formal Authority System		
a. Departmentation	Interdependent	Autonomous
b. Delegation	Decentralized	Centralized
2. Formal Control System		
a. Standards	Diffuse	Specific
b. Rewards-Penalties	Institutional	Individual
3. Information System		
a. Communication Nets	Unrestricted	Restricted
b. Channel Density	Informal	Formal

LEADERSHIP PROCESS	DEMOCRATIC to	DIRECTIVE
1. Representation	Upward	Downward
2. Interaction	Lateral	Vertical
3. Participation	Extensive	Limited
4. Goals	Group	Individual
5. Direction	Loose	Close
6. Rule Adherence	Low	High
7. Inducements	Rewards	Penalties

ORGANIZATIONAL EFFECTIVENESS	LOW to	HIGH
1. Individual Effectiveness: Motivation		
a. Job Involvement	Low	High
b. Commitment to Standards	Rare	Always
c. Initiative	Little	High
d. Self-Improvement	Little	High
e. Work-goal Commitment	Rare	Always
g. Satisfaction	Low	High
h. Sense of Achievement	Rare	Always
i. Job Attendance	Low	High
j. Job Commitment	Low	High
2. Intragroup Effectivess: Lateral Relations		
a. Confidence and Trust	Rare	Always
b. Job Related Communication	Rare	Always
c. Non-job Related		
d. Communication	Rare	Always
e. Cooperation Patterns	Rare	Always
f. Group Coheseiveness	Rare	Always
g. Interaction Off the Job	Rare	Always
3. Intragroup Vertical Effectiveness		
a. Trust and Confidence Downward	Rare	Always
b. Trust and Confidence Upward	Rare	Always
c. Requested Information Communication	Rare	Always
d. Screening Job Information	Rare	Always
e. Human Relation-Information Upward	Rare	Always
f. Cooperation and Teamwork	Rare	Always
g. Acceptance of Supervisor's Decisions	Rare	Always

THE STUDY

The study was designed to test the relationship between structure, process and effectiveness in organizations. Initial investigation focuses on significance and direction of influence of interaction effects between contextual and managerial structure, and between structure and leadership.

HYPOTHESES

The following hypotheses were tested:

1. As context moves from simple to complex, and managerial structure moves from simple to complex individual, intragroup and vertical effectiveness will move from low to high. The interaction effect is positive.

2. As context moves from simple to complex and leadership style moves from democratic to directive individual, intragroup and vertical effectiveness moves from low to high. The interaction effect is positive.

3. As managerial structure moves from simple to complex and leadership style moves from democratic to directive individual, intragroup and vertical effectiveness moves from low to high. The interaction effect is positive.

4. As context and managerial structure move from simple to complex and leadership style moves from democratic to directive individual, intragroup and vertical effectiveness move from low to high. The interaction effect is positive.

SAMPLE

The sample consists of 772 individual responses collected in 32 organizations. There is a heterogeneous mix of organizations including: telephone companies, chemical manufacturing, schools, data processing firms, retail stores, community service organizations, hospitals, machine manufacturing, rubber manufacturing, steel foundaries, plastics manufacturing, restaurants, supermarkets and city government units. At least four different groups within an organization were sampled. Data was collected by questionnaire and interview.

METHODOLOGY

The independent variables of structure and leadership were measured on Likert-type nine point interval scales. The dependent variables of individual behavior, intragroup behavior and vertical intragroup behavior were also measured on nine point scales. Behavior questions are worded to assess the frequency of occurrence of activities and feelings in the organization. For example. "What percentage of the time do you think about leaving your job?" Structure questions are directed at observable dimensions such as, "The number of people assigned to your formal unit." For a detail development of the questionnaire see A. Melcher [6].

Subdimensions of primary and secondary structure, leadership, individual behavior, intragroup behavior and vertical intragroup behavior were aggregated to arrive at the main dimensions (see Figure 1). The dimensions were then entered in multiple step wise regressions for each of the three dependent variables.

Interaction effects were assessed by entering a new variable generated by the multiplication of the two or three interacting variables as discussed in Neter and Wasserman [8]. The interpretation of the interaction effect follows from this new variable.

RESULTS

The product moment correlations between the independent variables and each of the three dependent variables are shown in Table 1.

TABLE 1

CORRELATIONS BETWEEN ALL VARIABLES (n=772)

	1	2	3	4	5	6	7
1. Context	---						
2. Context X Managerial	.81	---					
3. Leader X Context	.81	.69	---				
4. Leader X Managerial	.03	.45	.43	---			
5. Lead X Context X Manager	.68	.89	.86	.73	---		
6. Individual	-.05*	-.05*	-.24**	-.24**	-.20**	---	
7. Intragroup	-.06*	-.02	-.26**	-.22**	-.18**	.22	---
8. Vertical	-.02	-.04	-.33**	-.39**	-.29**	.46	.42

*Significant at .10 level ** Significant at .001 level

SIMPLE CORRELATIONS

For the simple correlation run context is negatively correlated with individual, intragroup and intragroup vertical effectiveness. The relationship is significant only for individual and intragroup. The results of the simple correlation support the hypothesis that contextual structure has a negative effect on organizational effectiveness.

The interaction variable of context managerial structure is negatively correlated with all three types of effectiveness but is only significant for individual. In this simple correlation the negative effect does not support the hypothesis.

The effects of leadership X contextual structure are negative and significant for all three types of effectiveness. The hypothesis of a positive effect is not supported.

The combination of leadership with managerial structure is the same as with contextual structure. The three-way interaction effect also produces negative effects.

Simple correlations were reported to show single effects of direction and significance. These are useful for an initial analysis. The variables occur in reality as a multivariate system of effects. To determine how the total system influences behavior a multiple regression was used.

MULTIPLE REGRESSION

The main effects of managerial structure, contextual structure and leadership were included in the list of independent variables as well as the interaction variables for the multiple regression runs. The results are summarized in Tables 2,3 and 4.

TABLE 2

THE EFFECTS OF STRUCTURE AND

LEADERSHIP ON INDIVIDUAL BEHAVIOR

Variable	Beta	F-test	R^2
Leadership	-1.18	60.49*	0.12650
Context X Leadership	0.86	4.87*	0.12984
Context X Managerial X Leadership	-1.36	3.49*	0.13081
Managerial Structure	-1.10	2.82*	0.13377
Contextual Structure	-0.96	1.29	0.13455
Managerial Structure X Leadership	1.39	2.16	0.13503
Context X Managerial	1.43	1.79	0.13709

*Significant at .05 level

The F-ratio for the regression equation was 17.04 significant at the .001 level. The results indicate that context has a negative effect but is not significant. The interaction effect of contextual and managerial structure is positive and significant. Similiarly the interactions of context and leadership are positive and significant supporting the hypothesis that leadership offsets the negative

effects of context. The three-way interaction is however negative, indicating that the negative effect of directive leadership overwhelms the interaction of the structure variables. Leadership is a powerful variable, as it explains the most variance. The effects of the independent variables on intragroup effectiveness are summarized in Table 3.

TABLE 3

THE EFFECTS OF STRUCTURE AND LEADERSHIP ON INTRAGROUP EFFECTIVENESS

Variable	Beta	F-test	R^2
Leadership	-0.49	59.79*	0.13137
Context X Leadership	0.36	14.68*	0.13689
Context X Managerial	1.34	10.67*	0.14778
Managerial X Leadership	0.47	5.72*	0.15304
Context X Managerial X Leadership	-0.84	1.53	0.15477
Context	-0.85	1.04	0.15499

Significant at .05 level

The F-ratio for the regression equation is 19.82 significant at the .001 level. The interaction effect of context and managerial structure is positive and highly significant. Both interactions of structure with leadership are positive and significant. The three-way interaction is again negative but not significant. The interaction effect of context and managerial structure is more important for explaining intragroup than individual effectiveness. The effects of the independent variables on vertical intragroup effectiveness are summarized in Table 4.

TABLE 4

THE EFFECTS OF STRUCTURE AND LEADERSHIP ON VERTICAL INTRAGROUP EFFECTIVENESS

Variable	Beta	F-test	R^2
Leadership	-0.58	143.10*	0.30997
Context X Leadership	0.32	3.95*	0.31085
Context X Managerial	0.71	3.27*	0.31156
Managerial X Leadership	0.15	2.68*	0.31371
Context	-0.47	0.65	0.31407
Context X Managerial X Leadership	-0.57	0.26	0.31430
Managerial Structure	-0.22	0.14	0.31442

*Significant at .05 level

The F-ratio for the regression equation was 49.20 significant at the .001 level. The same result is obtained for the three-way interaction as was found for intragroup effectiveness. The interaction effects of structure and leadership and context and managerial structure support the hypotheses.

Again, leadership is an important variable as would be expected since vertical behavior measures behavioral processes between leaders and subordinates. Structure alone is not important but in combination with other variables rises to significance.

The results of the regression analysis give us different insights into the effects than the simple correlation results. We see the model operating as a total system. It is difficult to determine how the multicolinearity of the variables effects the R^2 values, for this reason we cannot attach much importance to the final size of the R^2. Even if we set this consideration aside the R^2 values are affected by the heterogeneity of the data. If we can explain 31% of the variance in vertical behavior over a cross-section of organizations the results would certainly be very encouraging if the data were partialed out by type of organization.

For purposes of this piece of research the sign of the beta and the F-test are important. The results obtained are encouraging especially since the data is heterogeneous

SUMMARY AND CONCLUSION

The purpose of this research was to test the effects of organization design on three levels of effectiveness within the organization. A large data base consisting of a cross-section of organizations was used. Four hypotheses tested the interaction effects of contextual and managerial structure and the interaction of structure and leadership. Results showed that leadership interacts with structure, supporting a contingency theory of leadership. A directive style of leadership offsets the negative effects of both increasing contextual and managerial complexity. This finding provides a new insight into how leadership can be used in an effective organization.

The positive interaction effect of context and managerial structure is of interest to the organization designer. It supports the importance that should be given to the design of the formal authority system, control system and information system. There is little that can be done to change context in the short term. This is not true of the managerial system which gives management an effective means of offsetting contextual variables. This study contributes to the development of a contingency theory of organizational effectiveness and has important implications for the management of the acquisition process. As the process moves toward increased complexity greater effectiveness of individuals and groups can be achieved by designing the organization to compensate for the breakdown in processes that occur or by employing a directive style of leadership on the part of the program manager, or some combination of both techniques.

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CONTRACTOR MOTIVATION

CURRENT PROBLEMS IN THE ACQUISITION OF MAJOR WEAPON SYSTEMS

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ABSTRACT

This paper analyzes the impact of several procurement policies employed in the acquisition of major weapon systems. The inadequacies of the traditional approach to competitive procurement are examined, and alternative strategies to increase the level of competition throughout the life of the system are described. Barriers to competition created by the Armed Services Procurement Regulations are also discussed.

The policy of Design-to-Cost is analyzed, with emphasis upon the ramifications of this procedure for cost control and innovation. Also considered are several deficiencies in data and methodology by which cost constraints and estimates are derived.

THE EFFECTIVENESS OF INCENTIVE CONTRACTS: WHAT RESEARCH TELLS US*

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INTRODUCTION

Incentive contracts are now a part of DOD contracting officers repertoire. The present incentive environment can be directly traced back to the early sixties (see Exhibit 1), specifically to the efforts of the former Secretary of Defense, Robert S. McNamara (1:4-7). However, incentive contracts are by no means a recent innovation. Both the Monitor of the Civil War and the Wright brothers' "heavier-than-air-machine" were purchased with an incentive contract (1:8-9). The Monitor had to be floated, attain a specified minimum speed, and win its first battle before the contractor was paid.[1] The Wright brothers received a $5,000 bonus added to their $25,000 contract when their flying machine exceeded the target speed by two miles an hour (1:8-9).

Given our recent experience with incentive contracts, three questions need to be asked: (1) are these contracts effective? -- that is, do they accomplish the government's goals and objectives? (2) are these contracts efficient? -- that is, do the benefits outweigh the costs? and (3) can the government's use of these contracts be enhanced. This paper will attempt to find the answer to these questions by reviewing completed research projects. These research projects range from consultants' reports to Ph.D dissertations. However, this paper will limit itself to research projects that studied DOD incentive contracts and to projects that are currently readily available to any contracting officer that wants to investigate a particular point raised in this paper.

DEFINITIONS

This paper will focus on the following contract types:

(1) firm fixed price (FFP);
(2) fixed price plus incentive (FPI);
(3) cost plus incentive fee (CPIF); and
(4) cost plus award fee (CPAF).

When the firm fixed price the contractor receives only the original price negotiated prior to the awarding of the contract, unless for some reason the contract is changed during its duration. The fixed price plus incentive has a target cost and profit, a ceiling price, and a share ratio (which defines the percentage of cost under- or overruns for which the government and contractor are responsible). The CPIF has a target cost and fee, a minimum and maximum fee, and a share ratio. The CPAF has an estimated cost, base fee, variable award fee (which is subjectively determined following evaluation of performance as measured against the performance criteria set forth in the contract, a maximum fee (base fee plus award fee pool), performance criteria, and fee payment plan.[2]

THEORY

The contracts may be designed to give a contractor an incentive to decrease costs, increase performance of the end-product, or some other governmental goals, such as a prompt delivery. The incentives that this paper will deal with will be only the contractual incentive within the contracts.[3]

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* Opinions, views or conclusions expressed by the authors in this document are their own and are not to be considered or interpreted as official expression, opinion, or policy of The Department of the Air Force.

** The research assistance by the Air Force Business Research Management Center is gratefully acknowledged.

1. The first two conditions were met and although the Monitor only fought the Merrimac to a draw, the contract was paid (1:8).

2. The characteristic of each of these contracts and the proper use of each type of contract is adequately covered in the Armed Services Procurement Regulation (ASPR) (7:Section 3, Part 4) and in the DOD and NASA's Incentive Contracting Guide (8) and therefore will not be covered in detail in this paper.

3. Other authors make a destinction between these contractual incentives and "internal incentives" such as the Design-to-Cost system. See for example, Robert W. Blanning, Paul R. Kleindorfer, and Oreet Zohar, Survey and Annotated Bibliography on Literature Pertaining to Internal Financial Incentives in System Acquisition prepared for The Office of Naval Research. Contract number N00014-77-C-0171 (February 1978).

EXHIBIT 1
AWARDS BY TYPE OF CONTRACT PRICING PROVISION (By Fiscal Year) (a)

Type of Pricing Provision	Fiscal Year 1960	1965	1970	1975	1977
TOTAL (b)	100.0%	100.0%	100.0%	100.0%	100 0%
FIRM PRICE TYPE (SUB-TOTAL)	57 4	76.5	74.0	72.3	72 9
Firm	31.4	52.8	47.5	41.1	39 4
Redeterminable	6.1	2.2	0.7	1.0	1 5
Incentive	13.6	16.6	20.9	17.8	20.1
Escalation	6.3	4.9	4.9	12.4	12 0
COST REIMBURSEMENT AND OTHER TYPES (SUB-TOTAL)	42.6	23.5	26.0	27.7	27.1
No Fee	2.2	2.4	1.9	2.8	2 2
Fixed Fee	36.8	9 4	10.4	10.6	10.8
Incentive Fee	3.2	11.2	9.8	12.1	11 4
Award Fee	0.0	0.0	3.1	1.6	1.9
Other (c)	0.4	0.5	0.8	0.6	0 8

(a) For definitions and coverage, See Notes on Coverage Exclude data for the Armed Services Petroleum Purchasing Agency (ASPPA) from July 1950 through December 1956, but includes data for Military Petroleum Supply Agency, the successor to ASPPA, beginning 1 January 1957 Excludes Army Procurement overseas prior to fiscal year 1958 and also excludes some Navy letters of intent in fiscal years 1951 and 1952 for which type of pricing provision was not determined.
(b) Represents procurement actions of $10,000 or more excluding Intragovermental, except for fiscal year 1951 which included Navy actions of $5,000 or more and Army actions of $100,000 or more.
(c) Includes Time and materials and Labor Hour contracts.

Source: Military Prime Contract Awards, (Fiscal year 1977). Washington, D.C.: Office of the Secretary of Defense. pp. 67-65.

Although both the Armed Services Procurement Regulation (7:Section 3, Part 401) and the DOD and NASA Incentive Contracting Guide (8:1-2) recognize that the contractor is motivated by more than just a profit, the profit motive is considered essential to successful implementation of an incentive contract. As the Incentive Contracting Guide states:

> The profit motive is the essence of incentive contracting. Incentive contracts utilize the drive for financial gain under risk conditions by rewarding the contractor through increased profit for attaining cost (and sometimes performance and schedule) levels more beneficial for the Government than expected (target) and by penalizing him through reduced profit for less than (target) expected levels. In stressing the profit making aspects of a company's existence, however, there is no intention to discount the importance of extracontractual incentives... (8:102).

Logistics Management Institute found the following four primary justifications for the government's use of incentive contracts:

(1) Incentives motivate efficient contract management and achievement of a high performance product.
(2) Incentives enable the government to reward contractors on the basis of demonstrated management ability and product performance.
(3) Incentives assign to the contractor a larger portion of contract risk than he would bear with a cost plus fixed fee (CPFF) contract.
(4) Incentives provide explicit communication of the government's contracting objectives (20:3).

INCENTIVE CONTRACTING: RESEARCH FINDINGS

The early incentive-contracting research studies were on a theoretical level or, because of limited data, exploratory. As more data became available, more empirical testing was possible. Thus, the later studies have tended to be largely empirically based. Rather than cover the research in the typical chronological fashion, this author proposes to discuss the findings in the six following areas: incentives as motivators, incentives as a means to reduce costs, incentives for better scheduling, incentives for better performance, award fees, and improving the use of incentives and future research needed.

INCENTIVES AS MOTIVATORS

As earlier noted, both the ASPR and the DOD and NASA Incentive Contracting Guide consider the profit motive of the contractor essential to the successful use of incentive contracting An "incentive is not a motivator if it does

not satisfy a need of the recipient. Thus, the first question that needs to be addressed is whether profit is a primary goal of the contractors in today's envirorment.

When Jones and Pierre asked fifty contractors to rank the most important motive of their industry, a plurality selected profit maximization over firm perpetuation, sales maximization, and socio-economic considerations (19:44). Forty-six percent of the contractors selected profit maximization as the most important motive, as compared to only 41 percent that selected firm perpetuation. However, the 30 government contracting officers that responded to the survey reversed the order of the contractors (19:44). Only 43 percent of the officers selected profit maximization as the primary motive and 47 percent selected firm perpetuation (19:44). Thus, there was an apparently different perception of the importance of profit maximization between contractors and government contracting officers. This study was limited both by its sample size and by the oversimplified questionnaire.

The most through and rigorous analysis of the economic motivations of contractors was conducted by Professor Raymond G. Hunt of the State University of New York at Buffalo. After an extensive review of the literature, a questionnaire, and interviews, Hunt concluded that:

> If we had to identify a single overarching company motive...(at least the R & D corporation participating in this research) it would not be profit-seeking; we would probably call it 'mastery' -- a desire to be in control of one's own fate, to be able to conduct affairs as one wished and to be good at it.
> This motivational orientation subsumes most other 'needs' as instruments for its achievement. Profit, for example, is a way of accumulating capital resources allowing an organization to make decisions partially independent of its customers (17:151).

In general, Hunt concludes that R & D contractors were basically a "risk averse group of firms...(that could) best (be) described as 'profit satisficers'" (17:297). In an experiment with sixteen undergraduates, Feeney, McGlothlin, and Wolfson of The RAND Corporation also found that the profits sought increased with uncertainty (11:v), which again implies risk averse behavior. It should be noted, however, that the motives of an organization can only be determined by inference--by studying its behavior or surveying the component members of the organization. Thus, it is the individual members that collectively define the motives of an organization. Consequently, an incentive must be perceived as a reward to the decision-makers of the organization.

Hunt's work implies that incentive contracts can be written to accomplish that goal. However, Hill and Shepard's Naval Postgraduate School's thesis questions whether incentive clauses really motivate middle managers (16:41). Since they found no profit maximization scheme in the seven companies they survey, they questioned whether profit incentives could be motivators (16:41) However, this study, like that of Jones and Pierre, was limited by small sample size and by the wording of the questions.

Thus, we are left with the comprehensive study of Hunt (17&18) that concludes that the motives of contractors are most complex, but amenable to incentive contracting.

INCENTIVES AS A MEANS TO REDUCE COSTS

Peck and Scherer found that government buying agencies controlled program costs less effectively than schedule and quality factors (24:440). Fox quotes former chief contract negotiator of the Navy, Gordon Rule, that cost controlling programs were resisted by the contractor and by the government personnel (12:435). The late Professor John F. Gorgol, formerly of Rutgers University, stated that government contractors were hampered by their lack of knowledge of what the actual cost of a product should be (14:44645). It was with this background the government attempted to give contractors as an incentive to control costs.

One initial problem with the incentive type contract is the difficulty in distinguishing between the high- and low-cost firms on the basis of the submitted bids or target costs (21:48). As John J. McCall of The RAND Corproation points out, the sharing of excess cost and profits efficient (low-cost) firms are induced to submit target costs higher than the expected cost, thereby reducing the amount of profits they would have to share (21:48). On the other hand, inefficient (high-cost) firms are encouraged to submit lower target costs than expected costs, since the government will share their losses (21:48). McCall hypothesizes that this problem will become less severe as the sharing proportion of the corporation rises (21:48). However, when Deavers and McCall tested the hypothesized correlation between sharing rates and efficiency (efficienty is the difference between target and actual costs), they found no statistically significant relationship (8:24).

There have been a series of empirical studies suggesting that incentive contracts have not been effective in controlling costs. As Fisher points out, the efficiency (in controlling costs) of types of contracts can no[illegible]ted unless [illegible] type of product produced was held constant (12:79). That is, the uncertainty of the cost of the end product was typically higher in cost type contracts than fixed price contracts. Fisher found no significant difference in cost growth of contract that could be attributed to contract type (12:79). However, he found significant differences between contractors; some contractors consistently had larger underruns than others (12:79).

Besides the difference in uncertainty of the various types of contracts, there was also the problem of contract changes. A contract could be changed for some engineering reason to avoid reporting a cost overrun (12:Ch.19). However, Belden was not able to "conclude (in his study) that target costs were increased in order to reduce potential overruns or increase potential underruns" (1:95).

In the same study of 834 contracts, Belden found that the overrun/underrun contract outcome was independent of the size of the sharing ratio and of the type of contract (1:96). However, the size of the overrun/underrun was predicted by the type of work (production or R & D) (1:96). These conclusions were retested by Parker using a much larger sample size (2,683 contracts) and a longer time period. His results differed slightly from Belden's as can be seen in Exhibit 2. R & D contracts still had higher changes and overruns (23:42). However, contrary to his expectations overruns tended to increase as the contractors share ratio increased (23:43). Furthermore, CPIF contracts had substantially larger overruns than FPI or CPFF contracts (23:42). Again there was the problem of controlling for the difference in risk factors of contract type of work. Thus, the risk of the underlying work may be more responsible for the overruns/underruns than the type of contracts.

Both Belden and Parker found contractors acting in a risk averse manner. As the risk of the type of contract increased, so did the "going-in" (target) profit (1:114; 23:56-59). Parker also found that going-in profit rates were slightly higher with R & D contracts than production contracts (23:59). However, both Belden and Parker found higher "coming-out" (actual) profit rates for production contracts than R & D contracts (1:114; 23:59-60). Coming-out profit rates remained higher for FPI than the CPIF or CPFF in both studies (1:114; 23:59).

Belden and Parker found that there was a relationship between delivery dates and

EXHIBIT 2
AVERAGE CONTRACT CHANGE AND OVERRUN

a Data by Type of Contract

Type of Contract	Number	Mean Change*	Mean Overrun**
FPI	439	[illegible]7.5%	2.[illegible]%
CPIF	448	34.9%	[illegible]
CPFF	1796	85.[illegible]%	2.1%

b Data by Type of Work

Type of Work	Number	Mean Change	Mean Overrun
Production	1054	51.9%	1.5%
Research and Development	1619	75.3%	4.0%
COMBINED TOTAL	2683	66.0%	3.0%

* Change % = (adjusted contract target ~~contract~~ cost - initial contract target cost) ÷ initial contract target cost

** Overrun % = (final contract cost - adjusted contract cost) ÷ adjusted contract cost

Source. Parker (23:22)

overruns. The more closely the schedule was met, the lower the cost overruns (1:96; 23:43).

According to Hunt, the real advantage to cost incentives is that they act as a counterweight to the performance bias of high technology organizations (17:306). As he states, "They can say quite simply, 'go ahead and do good work -- right on! -- but try to hold down the costs, too, and we'll pay you if you do.'" (17:306).

INCENTIVES FOR BETTER SCHEDULING

Hunt simply states, "schedule incentives probably...(were) superfluous" (17:306). However, both Belden and Parker found that there was a significant tendency for schedule delays and overruns to occur together (1:96; 23:43). Conversely, Parker found that early delivery and underruns were apt to occur together (23:43). Belden found that schedule incentives tend to be at least partially lost rather than earned.

Thus, we find that if schedules were met, cost incentives were earned. However, we do not know whether schedule incentives were redundant with cost incentives or whether they have an information valu[illegible] their own. If incentives were designed pa[illegible]lly as a means of conveying explicit information from the government contracting officer and the contractor as the LMI Study (20:3) suggests, then schedule incentives were not superfluous, even if unearned. Furthermore, if schedule incentives are not included, then the contractor may make an "undesirable" (from the government's point-of-view) trade-off to earn a performance or cost incentive.

INCENTIVES FOR BETTER PERFORMANCE

Hunt concludes that most organizations were oriented more toward performance than toward cost-reduction (17:306). Thus, he states performance incentives were probably redundant with the "natural" organizational tendencies and therefore contribute little to program management and performance control (17:306).

Both the studies of Belden and Parker came to the same conclusion that performance incentives were typically earned regardless of cost overrun/underrun outcomes (1:96; 23:43).

In a study exclusively of civil engineering service contracts, Ehnert and Kaiser found no statistically significant relationship between contract type (fixed or incentive) and performance (10:47-48). They studied 35 service contracts where performance was a measure of the number of complaints, the fewer complaints the better the performance rating. These findings supported Hunt's conclusion that there was a performance bias of organizations.

However, just as with schedule incentives, not including performance incentives may send a negative message to the contractor. That is, a lack of performance incentive may be interpreted by the contractor as a message that the government has no real interest in performance.

AWARD FEE

In contrast to the numerous studies that have focused on incentive fee contracts, there has been little research on award fee contracts. That may be a function of the fact that few contracts used the award fee provision. As can be seen on Exhibit 1, less than 2 percent of all contracts, as measured by dollar amounts, used award fee contracts in 1977. The other reason that award fee contracts may not have been more [illegible]nsively researched is that they are a relat vely new type of contract. Although they have been applied by NASA since the early sixties, they have been used only on an experimental basis by the Army, Navy, and Air Force until 1968 when the award fee contract type was included in the ASPR (1:30).

An early study of Navy and NASA contracts, by Douglas Egan, concluded that the major "incentive" in the award fee system may "arise from the fact that a formal record of evaluated performance is maintained," rather than from the immediate fees earned (9:24).

Dr. Hunt theorized that award fee contracting should be structurally simpler, but more demanding to administer, than other types of incentive contracting (18:158). Hunt also points out that CPAF comes closer than other contract types to fulfilling the principle that profits should be earned, not awarded in advance (18:153). The CPAF thus meets one of the Logistics Management Institute's four justifications of incentive contracts better than the other incentive fee contracts. Specifically, "incentives enable the government to reward contractors on the basis of demonstrated management ability and product performance" (20:3). However, as he points out, CPAF does not hinge on the primacy of the profit motivation; rather it enhances performance, because award fee contracting improves the communication between the government and contractor (18:154-57). Thus, CPAF acts as a management tool of the government on the contractor. As Hunt states, "award fee is best regarded as a method of management, not as a contract type" (17:164).

If CPAF is to be considered a management tool, then there should be a learning-curve effect over the life of the contract. That is, if partial awards are made, the contractor is able to discern what is important to the government. In a study of 13 CPAF contracts, Mel D. Byers of the USAF found such a relationship. He found that the "percentage of award fee the contractor earned seemed to increase" as the contract progressed (4:86).

A study done by two Air Force officers, Jack R. Runkle and Gerald D. Schmidt, further supported the conclusion that an award fee contract was a management tool. In a study of 56 contracts they found that if the fee determination officer (FDO) was five supervisory levels above the buyer, then the percentage awards fee the contractor earned was higher than if the FDO was only four levels over the buyer. They also found that the satisfaction of the government (as measured by the percentage award fee paid) was higher as the frequency of evaluations was increased. Moreover, they found that a pure CPAF was superior to a combined CPIF and CPAF but inferior to a combined FPI and CPAF contract (25:52).

Byers found no statistically significant relationship between the relative magnitude of the award fee and the level of contractor performance (4:81-82). In a study of 19 DARCOM contracts, Shirley H. Carter found that the following factors were not significantly related to the level of award fees: size of contract, magnitude of absolute potential award fee, and relative size of the potential award fees (potential award fee as a percentage of the estimated contract costs) (5:30-35). However, she found that the level

of award fees had a statistically significant negative relationship to the relative size of the fixed fee (as a percentage of estimated contract cost) (5:35-36). Similarly, the level of award fees had a statistically significant positive relationship to the relative size of award fees to total fees (5:36-37). Thus, Carter concluded that award fees are more effective motivators of contractor performance; however, relatively large fixed fees acted as a disincentive (5:36&40).

If one accepts the percentage of potential award fee earned as a surrogate for government satisfaction with a contractor's performance, then research has shown that award fees are an effective motivator. The usefullness can be increased by taking the following steps: make award fees a greater part of total fees in a cost type contract; combine it with an FPI, rather than a CPIF; increase the frequency of evaluation; select an FDO that is five, rather than four supervisory levels above the buyer; and use it on service contracts rather than hardware contracts.

Although CPAF may be effective motivators, are they efficient? That is, do the benefits of contractors' enhanced performance outweigh the costs of administering an award fee contract? This question has not been, and may never be, answered. For as Carter points out, "It...(is) quickly learned that it...(is) impossible to isolate the administrative costs (of CPAF contracts) with a reasonable amount of resources" (5:28).

IMPROVING THE USE OF INCENTIVES AND NEEDED RESEARCH

Most of the research reports surveyed in this paper included recommendations for improving incentive contracting. In this section some of the most commonly suggested recommendations will be listed. It must be added that all the questions about incentive contracting have not yet been formulated; thus, much is still unknown. For example, we still do not know whether incentive contracts provide for any true economic benefit -- do they return more than they cost? Nor, do we truly understand the best methods of motivating management. If contractors' primary motivation is to control their own fate, as Hunt suggests (17:151), then how do we provide incentives that complement this? If the contractor's primary motivation is risk reduction, can the government reduce the contractor's risk and save meney at the same time? Those questions, albeit fundamental, must remain for future research projects.

Several researchers have recommended that the types of contracts to use for a given procurement be more selective (for example, see 1:132). Incentive contracting will be more effective if it is selectively applied to the type of work and conditions that are amenable to profit incentives (20). A study may be undertaken to determine how closely the guidelines of ASPR and the Incentive Contracting Guide are followed and whether they should be revised.

Another method recommended to improve contracting in general, and incentive contracting specifically, is to look at the intercontract dependencies (1:133). That is, broaden the outlook of the government from a contract-to-contract view to a more long-term perspective. That was a company's long-run return and risk relationship with government can be examined in a meaningful manner. This approach seems to support Professor Hunt's view that we are dealing with "fluid operational environment with static and rigid contracts" (17:306).

Runkle and Schmidt, Parker, and Belden recommend that a study be initiated to determine the outcomes of incentive contracting for small firms (1:133; 23:66; 26:63-64). One of the strongest recommendations comes from Runkle and Schmidt. They maintain that when using award fee contracting, frequent evaluations be made from a supervisory position that is five levels above the buyer (26:62-63). Carter implies that the performance evaluation conversion schemes should be analyzed with the possible aim of devising a unitary system (5:41).

CONCLUSION

Professor Hunt warned us against "replacing one set of over-simplifications (the 'conventional wisdom') with a new set" (17:296). However, that is what was attempted in this paper. Volumes of extensive research were distilled into a few pages and in some cases, a single sentence. This distillation process will not be fair to the authors of the research or to the readers of this paper, unless the latter group goes back and reads the complete reports of the former group. This paper can be used to quickly locate the important research projects pertaining to his or her area of curiosity. This saves the reader a time-consuming and tedious search through the literature. Thus, this paper is designed as a means of locating the answers, rather than as the answer itself. Furthermore, the reader should always keep in mind that research, by its very nature, is a dynamic process. Many of the conclusions reached in this paper may be updated, revised, or reversed in the future.

If one wants to explore incentive contracting in general, I would recommend that the two Hunt studies (17&18), and the dissertations of Berhold and Belden be read for a thorough understanding of the theoretical foundations of incentive contracting. Peck and Scherer's Economic Analysis (24) and J. Ronald Fox's (12) book should also be read for a background to the economic environment of contracting.

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FACTORS THAT INFLUENCE ORGANIZATIONAL PERFORMANCE

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This study approached the question of what determines performance by organizations from three directions: (1) perceptions or beliefs of managers about what determines organization performance; (2) interrelations of measures of those beliefs with other measures of motivation; and (3) managers' views about what makes for effective R&D performance.

THE STUDY

As part of a larger NASA-funded study, questionnaires were obtained by mail from 1283 respondents employed by one or another NASA/DoD R&D contracting agency, or by a private R&D contractor. In addition, personal interviews were done with 64 technical managers in the same kinds of organizations. Respondents generally held middle- to upper-level management positions; all were males [2].

MEASURES OF PERFORMANCE

Performance Influence. On a six-point scale, respondents rated ten items which "may affect contractor performance of R&D contract." Means of these ratings are in Table 1, with the item rank orderings. As can be seen, most of the items are judged to express conditions having relatively strong effects on R&D performance. Only three items are rated toward the "weak" side of the scale. These are: "contractual possibilities for profit trade-offs" (by consensus the weakest of the ten influences), "quality of interpersonal relations within contractor organization" (which contractors think is more important than do government respondents), and "nature of procurement" (which government people think is more important than do contractors).

Government-contractor agreement in the ordering of the individual items is quite close. (The rank correlation between the sets of ratings is .94.) Hence, the "All Respondents" column of Table 1 conveys a consensus on the relative importance of the 10 itemized performance influences. It will be seen that the three most important perceived influences include two "structural" considerations (clarity of job specs and contractor's work plan) and a "motivational" one (prospects for production follow-on). The three least important influences were two "contractual" elements (nature of the procurement and contractual possibilities for profit trade-offs) and one "human relations" consideration (quality of interpersonal relations within contractor organization). It seems fair to say that project-particular "structural" influences were seen as weightier influences on R&D performance than were other kinds, and that important "motivational" orientations were long-term rather than short (cf. ratings on production follow-on vs. contractual profit trade-offs).

To explore the structure of the ratings on the ten R&D performance influence items they were factor analyzed with an orthogonal (varimax) rotation. Three factors resulted, explaining 48% of the variance before rotation.

The first factor reflects a task orientation, referring to planning and specification aspects of the project itself. The second factor refers to the contract as an influence on project performance. The third factor concerns interpersonal relations, both within the contractor organization and between it and the government sponsor. Factor scores were computed on each of these three factors, reflecting perceptions of factors which influence performance. These are found in Table 3. The tendency just noted for contractors to regard the influence of contract *per se* as lower than government people is evidenced there in a significant difference between their scores on the pertinent factor.

Environmental Constraints. Presented with ten pairs of items, respondents were asked their "views about the factors controlling contractor project performance." Each item pair included one statement claiming that organizational factors influenced some aspect of performance and another arguing that environmental factors influenced that aspect of performance. Respondents were asked to check the one item they "more strongly believe to be the case."

Table 2 shows pronounced asymmetries in the relative popularity of some of the two response alternatives. For example, the great majority of our respondents felt that "most project difficulties result from mistakes made by people;" they did not believe that "[they] are produced by essentially uncontrollable events and really are nobody's fault." Correspondingly, respondents said that "project outcome is mainly a result of operational decisions made along the way" instead of saying that "once a contract has been structured and a project initiated its outcome is pretty well determined," thereby, once again, downgrading the perceived importance of contract as a determiner of performance.

Some other items divided our respondents more evenly. For instance, roughly equal numbers of them said "for the most part my operational decisions are prescribed by regulations and

other higher-level policies," as claimed that "by and large I have a good deal of lattitude in making operational decisions as I see fit." However, this pair of items shows the only clear reversal of endorsement as between government and contractor respondents; two-thirds of the former endorse the first-mentioned alternative, whereas two-thirds of the latter endorse the second-mentioned one.

Intercorrelations among these ten items were extremely low. But, rather than treat them as separate perceptions, an "environmental constraints" scale was constructed by coding items as either environmental ("1") or organizational ("2") and summing the scores. Scores could thus range from a low of ten to a high of twenty. A low score reflects a perception that environmental factors constrain project performance. A high score reflects a perception that factors within the organization's control exert greater influence on project performance. This measure reflects the amount of uncertainty perceived in the organization's environment, as opposed to its capacity to control this uncertainty, and the effect on performance.

Mean scores on this scale are shown in the first row of Table 3. In general, they indicate that our respondents favored a belief in organizational ability to control its own performance, or to control uncertainty in its environment. Government respondents, however, were less convinced of this.

MOTIVATION AND PERFORMANCE

A common assumption in organization theory, procurement and project management alike is that an organization's performance reflects something about it and its members' "motives" [1]. Yet the relationship between motivation and performance has been studied much more often at the individual than at the organizational level [5]. Therefore, in this study we explored the structural linkages of motivation and organizational performance as these are implied by the relevant perceptions of organization members. Thus we used perceptual proxies for actual motivational and performance variables, and examined their patterning.

The dependent variable for this part of the study was respondents' perceptions of what factors influence the performance of a particular R&D project. Predictor variables, in hierarchic regression analyses, included respondents' perceptions of their organizations' motives and goals, their perceptions of their own personal goals, and their perceptions of environmental constraints which affect performance (measures of which we have just described). "Objective" predictor variables concerning background characteristics of the respondent and his organization also were used; it remains to specify these variables and to describe our measures of individual and corporate motivation.

Corporate Goals. Contractor respondents rated 40 items on a six-point scale as to "how important an influence upon policy or operational decision-making in the company for which you presently work do you believe it is." Government respondents rated the same 40 goals "for the typical firms with which you have had experience." The 40 ratings were subjected to a principal components analysis with an orthogonal (varimax) rotation. Nine factors appeared, explaining 58% of the variance before rotation [3].

Individual Goals. Respondents also rated their personal work goals on a six-point "importance" scale They rated them in the context of making "the decision as to whether to accept a new position open to you." A principal components analysis of these ratings, using an orthogonal (varimax) rotation, yielded seven factors explaining 56% of the variance before rotation

Table 3 displays factor scores by group for each goal. As can be seen, contractors see "effective performance" and "image-making" as more important, and "risk aversion" as a less important corporate goal than do government people. Complementarily, government respondents describe "safety-comfort" as a more important, and "esteem" and "power-responsibility as less important individual goals than do contractors. Overall, there was some relationship between corporate goals and individual goals, but it was not as strong as might perhaps have been expected [3].

Organization and Respondent Variables. Characteristics of the organization and the respondents were also used as predictor variables. These included: whether or not R (respondent) worked for the government or a contractor; and, for contractors, sales volume, percentage of government and R&D work. Also included are R's education and job function.

Findings from Regression Analyses. The basic question under investigation was whether perceptions of factors influencing organizational performance may be predicted from three other perceptual measures and six measures of characteristics of the respondent and his organization.

A series of one-way analyses of variance on the dependent variable was first completed to check whether differences in perceptions were systematically determined by differences in the background of the respondent or his organization. No substantial differences in managerial perceptions of organizational performance could be attributed to such background differences.

Following this, hierarchical regression analyses were done, taking managerial perceptions

of organizational performance as the dependent variable, with the other perceptual and background measures (treated as dummy variables) as predictor variables. (Intercorrelation among predictor variables was minimal.)

The large number of predictor variables (14 perceptual measures, 19 respondent and organization characteristics variables) probably make the regression coefficients produced by the regression analyses unreliable. As an alternative method of assessing the relative importance of groups of predictor variables, the increment in variance explained (multiple R^2) may be examined at each step of a stepwise hierarchical regression analysis.

Each of the three performance influence factors was taken as the dependent variable, in turn. All respondent characteristics variables were entered in the analyses on the first step, followed by the organization characteristics variables. Together these "objective" measures explained very little variance in the performance influence factors (R^2=.00-.03).

The perceptions of environmental constraints variable was entered on the third step of the analyses. This variable does not add much to the variance explained in the performance influence factors (R^2=.00-.03).

The individual goals factors were entered on the fourth step of the analyses and the corporate goals factors on the fifth step. Together they add about ten percent additional variance explained to the total (R^2=.10-.12).

The order in which variables are entered in a stepwise regression analysis affects the amount of variance they explain. The order of entrance used here reflects an attempt to assess the effect of the three predictor variables which are perceptual in nature on the dependent variable, once the effects of objective variables have been accounted for. The results suggest that the perceptual variables contribute most to the total variance explained, even beyond the variance explained by the objective variables, but the overall amount of variance they explain (between two and twelve percent) still is not substantial.

With respect to the question of what these perceptions reflect about the actual operating organization and/or its members we conclude that the evidence here, though not extensive, suggests that the perceptions are not mere epiphenomena, not simply an expression of the perceiver's viewpoint; instead they reflect the literal everyday life of the organization. And, they indicate that life to be rather disjointed: goals of the organization and its subsystems, as well as perceptions of environmental constraints, appear to be only weakly related to conceptions about what factors influence project performance. Some analysts have suggested that organizations are at worst irrational and at best satisficing[4], but the portrayal of organization decision-making implied by these results is somewhat surprising.

Assume that an organization's operations are the product of decision-making in multiple areas: the picture presented by the data at hand is that this decision-making is not at all integrated. Organization goals seemingly are determined without reference to environmental constraints on the meeting of those goals, or how those broad goals are related to the factors which influence the performance of a particular project. The integration may not in practice be so poor as is depicted by aggregating discrete perceptions of members of the organizations involved, but the fact that the imagery of these members suggest it to be so poor is noteworthy in itself.

EFFECTIVE PERFORMANCE

Our survey data dealt with the kinds of things that influence performance in general. Therefore, although one would expect overlap, in our interviews with project management personnel we raised the more particular question of what it took to produce effective performance. Space allows us only to summarize certain of our findings.

We asked each interviewee (N=64) what he believed to be "the essential conditions for effective [R&D] project performance," and coded their responses into five classes of categories: (1) understanding of work statements, specifications and the like; (2) availability of resources (financial, technical, and other); (3) modes of project organization; (4) relations between the contractor and the procurement agency; and (5) the effects of contracts.

By and large, our interviewees emphasized as contributors to effective performance such things as clear work statements and specifications, along with the availability of resources; they deemphasized modes of project organization, contractor-customer relations, and contracts, *per se*. However, of all the specific conditions for effective performance, the one most prominently mentioned was "having capable technical personnel."

CONCLUSIONS

A need for capable technical people to assure effective R&D project performance may seem obvious. But the idea may also have a less obvious implication. Placed in juxtaposition with, on one side, our interviewee's secondary emphasis on clarity and rationality of work statement, and, on the other side, with the somewhat disorderly or unintegrated view of organizational decision-making suggested

earlier, it encourages speculation that the effective technical manager is valued not only for his operational skill, but also for his ability to sort out "by hand," so to speak, the disparate, poorly organized flow of messages relevant to R&D project performance.

At any rate, clearly it is time to develop more systematically the basic theory of how perceptions of members of organizations relate to the behavioral reality of organizational structures. No matter how interesting and suggestive may be data such as those reported here, they leave essentially unanswered some basic questions of validity. Furthermore, in order to improve practical methodologies of project management and the procurement/acquisition process, more descriptive research is also needed to illuminate just how organizations really function.

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Table 1

Mean Scores of Respondents on Performance Influence Items

Performance Influence Factors	(426) Government Respondents	(829) Contractor Respondents	(1255) All Respondents
project itself			
contractor work plan	2.23 (3.5)[a]	2.19 (2)	2.20 ([illegible])
clarity of job specs	1.95 (1)	2.03 (1)	2.0[illegible] (1)
contract itself			
nature of procurement	2.67 (7)	2.95 (9)	2.[illegible]6 (9)
contractual possibilities for profit trade-offs	3.02 (9.5)	3.37 (10)	3.25 (10)
contract type	2.23 (3.5)	2.41 (4)	2.35 (4)
quality of interpersonal relations			
quality of contractor-sponsor communications during life of contractor	2.48 (5)	2.44 (5)	2.[illegible]5 (5)
closeness of monitoring and supervision of working-levels	2.56 (6)	2.61 (6)	2.59 (6)
quality of interpersonal relations with contractor organization	3.02 (9.5)	2.75 (7)	2.5[illegible] ([illegible])
miscellaneous items[b]			
contractor organizational structure	2.77 (8)	2.83 (8)	2.81 (7)
prospects for production follow-on	2.00 (2)	2.35 (3)	2.23 ([illegible])

[a] rank order of mean scores listed in parentheses.

[b] these items did not load on any factor.

note: scale range is 4 (strong effect) to 1 (weak effect)

Table 2

Perceptions of Environmental Constraints by Organization Membership

Pairs of Items	(435) Govt.	(841) Contractor	(1276) All
How projects turn out depends:	25.5%	19.9%	21.8%
(1) largely on events and decisions outside contractor's organization			
(2) almost entirely on contractor's own capabilities	74.5	80.1	78.2
Contractors' operational decisions guided by:			
(1) considerations other than contract	54.1%	50.9%	52.0%
(2) form and content of the contract	45.9	49.1	48.0
People in government procurement organizations:			
(1) have little influence upon contractors' operations	81.8%	79.3%	80.1%
(2) can have major influence upon contractors' operations	18.2	20.7	19.9
[illegible] operational decisions:			
(1) are prescribed by regulations and [illegible] policies	64.1%	34.5%	44.6%
(2) [illegible] a good deal of lattitude	35.9	65.5	55.4
Project difficulties are produced by:			
(1) essentially uncontrollable events	13.4%	10.7%	11.6%
(2) mistakes made by people	86.6	89.3	88.4
Project outcomes determined by:			
(1) [illegible]	15.0%	13.8%	14.2%
(2) [illegible] decisions along the way	85.0	86.2	85.8
Contractor top management:			
(1) [illegible] control operations	62.1%	59.3%	60.3%
(2) can influence operations	37.9	40.7	39.7
In policy formulation:			
(1) [illegible] levels have little influence	69.0%	62.4%	64.7%
(2) all levels have influence	40.0	37.6	35.2
Contractors can make plans:			
(1) but many uncontrollable events prevent [illegible] implementation	54.9%	59.0%	57.6%
(2) with good assurances of being able to implement them	45.1	41.0	42.4
Being a successful business organization is a matter of:			
(1) being in the right place at the right time	89.6%	90.2%	90.1%
(2) hard work and high quality performance	10.4	9.8	9.9

Table 3

Results of One-Way Analyses of Variance:

	Organizational Membership						
	government			contractors			F score
	$\bar{X}$*	SD	N	$\bar{X}$	SD	N	
perceptions of environmental constraints	16.49	1.64	435	16.96	1.56	841	*12.74
individual goals							
1) intrinsic	-.08	.97	410	.05	1.01	787	2.49
2) safety-comfort	-.25	.98	410	.13	.99	787	*19.89
3) rec[illegible]ition	-.03	1.03	410	.02	.98	787	.56
4) [illegible]	.20	1.05	410	-.11	.94	787	*13.03
5) [illegible]rpersonal relations	-.03	.97	410	.01	1.01	787	.44
6) pe[illegible]r-responsibility	.20	1.05	410	-.10	.96	787	*13.02
7) autonomy	.01	1.05	410	-.01	.97	787	.67
corporate goals							
1) effective performance	.22	1.09	397	-.12	.93	767	*19.42
2) reputation	-.11	.97	397	.06	1.01	767	5.21
3) safety-risk aversion	-.20	1.02	397	.10	.97	767	*11.44
4) organization maintenance	-.13	.93	397	.07	1.03	767	5.84
5) growth	.11	1.18	397	-.06	.89	767	3.59
6) image-making	.35	.97	397	-.18	.97	767	*39.03
7) technology	.00	.97	397	.00	1.02	767	.05
8) power	.15	1.07	397	-.08	.96	767	6.99
9) survival	.06	.95	397	-.03	1.03	767	.96
performance influences							
1) project itself	-.04	1.03	435	-.03	.96	841	.95
2) contract itself	-.23	1.01	435	.05	1.09	841	*11.51
3) interpersonal relations	.01	1.07	435	-.07	1.01	841	1.07

*p < .001

CONTRACT DISPUTES AND APPEALS: RESPONSIVE PROCEDURES ARE NEEDED

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Introduction

Administrative procedures for resolution of Government contract disputes have been a subject of controversy for many years. Recently, however, demands for procedures improvement have been voiced by almost all segments of the Government contract arena.

Contractors have become frustrated with the time-consuming expensive procedures. At the same time, economic conditions have forced contractors to saturate the appeals boards with claims involving relatively small monetary amounts. In turn, the increased number of small claims adds to the existing appeals backlog and thereby lengthens the overall time involved in the appeals process. As a result, competition suffers as more and more contractors become disgusted with the inefficiency and expense of the system. (5:2-3)

This study reviews administrative procedures, workload data, and processing timeframes for contract disputes and appeals to determine if revisions are needed. The problems examined include the contracting officer's dilemma and the Armed Services Board of Contract Appeals process for appeals involving $25,000 or less. Perspectives of several possible solutions to the problems are described. The study concludes that new procedures should be implemented to restore flexibility and responsiveness to contract disputes and appeal procedures. Several specific solutions are recommended for implementation in developing responsive administrative procedures.

Disputes

Government contract dispute procedures have been defined as the adminsitrative resolution of controversies arising under a Government contract, the final stages of which are adjudicative in nature. The primary purpose in using administrative procedures has been to provide an expeditious and inexpensive mechanism for settling disputes between contractors and the Government without resorting to the court system. When a contract controversy is defined as a dispute subject to the administrative procedure, the contractor acquires an avenue for prompt settlement and forgoes the breach of contract remedy. (6:1) That avenue for prompt settlement begins with the Government's contracting officer.

A contracting officer's authority to resolve disputes is one of the most challenging and yet one of the most unregulated of the authorities granted. The Armed Services Procurement Regulation only briefly covers disputes and appeals procedurally in ASPR 1-314. The failure of the regulation to provide adequate guidance and to fully address the extent of negotiation and adjudication of disputes at the contracting officer level has been responsible for an increased volume of appeals. (3:2) In addition, the contracting officer confronts a dual-role dilemma.

In most disputes there have been attempts to negotiate a compromise mutual agreement in an effort to resolve the problem. If unresolved, the controversy deepens and becomes static as each side becomes more firm in its own position. The contracting officer represents the Government and protects what is believed to be the Government's interest. The contractor protects his own interest in this adversary stage of the dispute. In this stage, the contracting officer is reflecting his responsibility to the Government, his employer, as required by regulation. Assuming that the Government's position is based on good faith and sound judgement, it is the contracting officer's duty to enforce the position. It is also natural for the contracting officer to associate very closely with the Government position since, in fact, it is the result of his personal conclusions based on a review of available information and staff coordination. Regardless of advice, assistance, or support obtained, the decision is the personal responsibility of the contracting officer. Therefore, from the contracting officer's perspective, there is something akin to "pride of authorship" that may reinforce the contracting officer's position and increase the adversary nature of the dispute. (1:73-74)

When the contractor requests a final decision from the contracting officer, the contracting officer's role changes. The role changes from one involving discussion and negotiation of positions to one of the quasi-judicial nature. In this new role, the contracting officer is required to render a fair and impartial decision, based on the available facts and legal advice, and the contractor is required to proceed with contract performance in accordance with the contracting officer's decision. One author has compared the dual role as analogous to a lawyer arguing a case, and then putting on the judicial robes and rendering the decision on the case just argued. The personal equation is difficult to exclude from the official position of a contracting officer. The problem, then, is that the same individual is making a final decision as to the validity of his own previous arguments and conclusions. Human nature normally dictates the outcome of this dual role dilemma. (1:75)

One perspective of this problem is that, despite the best of intentions, integrity, and talent, contracting officers are, like everyone else, human, and therefore subject to human fallibility. (1:76) A second perspective states that contracting officers do not render decisions in a fair and impartial manner and have ignored their judicial role in most disputes. This is attributed to lack of motivation to settle the dispute at any point less than completely favorable to the Government. This perspective contends that contracting officers must pursue an adversary role in order to protect themselves; realistically, shifting roles is difficult. In short, this perspective states that the contracting officer would prefer to shift the dispute to ASBCA without judicial consideration n his part. (3:1-7)

In summary, contracting officer's duties require that they be prepared to change roles in contract dispute situations, and the dual roles are perceived as a dilemma which requires expanded procedures for proper resolution. However, this dilemma is only the first problem. A second problem area arises when an appeal of the contracting officer's final decision is filed with the Armed Services Board of Contract Appeals (ASBCA).

Appeals and the ASBCA

The problem presented here deals with the current process of appealing a final decision and the lack of responsive, inexpensive procedures for appeals under $25,000.

An appeal to the Board is initiated by a notice of appeal which is filed with the contracting officer. Within 30 days after the appeal is docketed at the Board, the appellant must file the formal complaint setting forth clearly the basis of each claim and the dollar amounts involved. The Government must file an answer to the complaint and the various claims. Either party may submit a pre-hearing brief. Also, either party can request a hearing or may submit its case on the basis of the record. Testimony and other evidence may be introduced and the proceedings are recorded as a trar :ipt of record. The procedures have becom ighly judicial in nature because of several landmark court decision and Congressional legislation which affected the Board procedures. (6:41-43) The incorporation of the court decisions and Federal legislation has forced the Board to provide more due process constraints in their proceedings. As a result, the Board procedures became more formal, more expensive, and more time-consuming. The contractor normally obtains an attorney and spends time in hearings, etc. Part of the problem revolves around the contractor's need for speed and economy versus the need for due process of law. (5:15-17)

Several other factors effect the procedures problem in addition to the increased due process factor. Among them are inflation and the increasing complexity of Government procurements. With the shift to increased use of fixed price contracts, inflation and defective specifications have forced contractors to file appeals and claims or face financial losses on many Government contracts. Therefore, the Board workload began to increase significantly. This, coupled with the additional time and expense caused by due process requirements, created the present situation in which appeals are time-consuming, expensive, and frustrating for both the contractor and the Government. In short, the procedures are no longer responsive to the need for efficient, economical, settlement of appeals. (4:354-358)

The following tables are intended to illustrate the workload and time problems involving appeals under the existing procedures. The information was furnished by the ASBCA. (9:1-6)

Table 1

Appeals Data
Armed Services Board of Contract Appeals
During FY's 1974-1977

	FY74	FY75	FY76	FY77
1. Method of Award:				
Advertised	558	669	544	462
Negotiated	429	387	374	371
2. Contract Type:				
Firm Fixed Price	768	777	757	713
All Other	198	259	161	120
3. Time of Docket (Days from date of docketing to date of decision):				
All cases:				
Average	442	420	387	451
Median	345	300	284	344
Rule 12 cases:				
Average	224	205	217	241
Median	180	193	179	211

Table 2

Dispersion of ASBCA Claims

* July 1973 - April 1974

0 - \$ 25,000	317=50.4%	(317/629 = 50.4%)
\$ 25,000 - \$100,000	147	
\$100,000 - \$500,000	99	
\$500,000 and up	66	
	629	

* May 1974 - April 1975

0 - \$ 25,000	360=52.6%	(360/684 = 52.6%)
\$ 25,000 - \$100,000	168	
\$100,000 - \$500,000	104	
\$500,000 and up	52	
	684	

* May 1975 - April 1976

0 - \$ 25,000	381=54.6%	(381/697 = 54.6%)
\$ 25,000 - \$100,000	134	
\$100,000 - \$500,000	131	
\$500,000 and up	51	
	697	

* May 1976 - April 1977

0 - \$ 25,000	311=51.0%	(311/610 = 51.0%)
\$ 25,000 - \$100,000	150	
\$100,000 - \$500,000	91	
\$500,000 and up	58	
	610	

* Period covered does not correspond to Fiscal Year: data was not provided on a fiscal basis.

It is apparent that the Board currently has a backlog. Also, appeals are substantially higher for advertised awards when compared to negotiated awards. Likewise, firm-fixed price (FFP) contracts are appealed a much greater percentage of the time than other types of contracts.

The "Time on Docket" information illustrates the time problem. The average time exceeds 1 year, and even the median figures, which discount extreme values, reflect a 10-12 month timeframe for adjudication.

Appeals of less than \$25,000 are approximately 50 percent of the total of all appeals filed during 1973-77. The Commission on Government Procurement found that 61 percent of the ASBCA appeals in 1972 were for less than \$25,000. (5:15) In either case, it is significant to the problem of responsive procedures.

The need for a flexible and responsive appeals system was also addressed by the Commission on Government Procurement. The Commission reported that the dictates of justice have emphasized due process at the expense of both speed and cost, and that the procedures have become formalized by demands for judicial type safeguards. Furthermore, the Commission found that the present procedures provide neither full due process for large, complex claims, nor a fast and inexpensive means of resolving small claims. The overriding problem with the present system, as determined by the Commission, is the attempt to adjudicate appeals and claims across the entire spectrum of size and complexity. (5:19-22)

POSSIBLE SOLUTIONS

Separation of Contracting Officer Roles

The contracting officer's dilemma has several possible solutions. Regardless of the ultimate solution to the dilemma, the regulations, particularly the ASPR, should be revised to better describe the proper actions and roles of the contracting officer during disputes and appeals. Many experts say the contracting officer is supposed to get the "best deal" possible for the Government; however, procurement regulations do not clearly define that requirement. There is almost no guidance on disputes. The roles should be analyzed and the regulations revised accordingly. When the negotiation of a claim breaks down, and the contractor requests a final decision, the ASPR should be more explicit in defining the requirements and content of a fair and impartial decision. Also, additional guidance is needed to insure that the negotiations are conducted with impartiality and a cooperative business-like approach. (3:11)

Perhaps the dilemma could be resolved by providing a separate contracting officer position at a higher procurement authority level (such as major command and USAF headquarters). The position should also be organizationally separated from the contracting officer involved in the dispute. This contracting officer, who could be called a Disputes Contracting Officer (DCO), would take jurisdiction of the dispute when notified that negotiations had failed. The DCO would be responsible to review the contract and all documents involved in the dispute. Informal arguments could be heard by the DCO prior to issuance of his final decision. An appeal to the Board could still be made by the contractor. Present procedures could also be revised to allow claims of less than \$25,000 to be submitted directly to a small claims forum or to the proper court if not settled by the DCO. The ASBCA process could be an option for small claims, based on contractor desires. The advantage to this procedure change is that a more impartial third party would make the final decision and the original contracting officer would not have to change

roles from negotiator to adjudicator. No new role would be introduced, but the judicial role would be filled by someone in a better position to provide impartial and fair treatment to both parties. (3:10) The impact of this suggested procedure appears to be a shift of responsibility and authority. In some instances, contractors and/or the contracting officer might fail to negotiate adequately, in order to pass the problem to the DCO for resolution. However, the basic concept seems to be a means of resolving the contracting officer dilemma. (1:81)

Appeals Under $25,000

A review of the dispersion of claims in Table 2 quickly discloses that approximately 50-55 percent of the monetary claims were for amounts of less than $25,000. Most authorities agree that claims in that category are considered to be small claims and should be handled in a reasonable rapid manner without lengthy involved procedures. The existing procedures have failed to provide adequate flexibility and responsiveness. (5:20)

A resolution proposed by the Commission on Government Procurement offers one perspective of a more responsive and flexible administrative system. The Commission stated that justice and efficient operation can best be obtained by a system which provides alternative forums for resolution of particular kinds of disputes. The contractor should be able to choose a forum based on his needs in each particular case; forums where the degree of due process can be judged against the time and expense involved. The Commission recommended establishment of a series of small claims boards as one means of providing fast, relatively informal and inexpensive adjudication of appeals claims of $25,000 or less. The small claims boards would be geographically dispersed and would operate under informal, accelerated procedures, with the present ASBCA no longer utilizing an accelerated procedure. (5:17-18) Under the solution proposed by the Commission, the contractor would have the option of filing an appeal involving $25,000 or less with either a small claims board, or the ASBCA, depending on the amount of due process, time and expense determined necessary by the contractor. Adverse decisions of the small claims board could receive a new trial in court, if desired by the contractor. This provision would tend to allow the small claims boards to remain informal and reasonably inexpensive. (5:22)

Another possible solution pertinent to claims under $25,000 concerns revision of the "Disputes" clause to provide coverage of "all disputes resulting from a contract." Specifically involved under this limited change are all appeals under $25,000. This solution provides that the ASBCA, or other boards formed to act on small claims, would be allowed to dispose of all appeals under $25,000, some of which presently must be decided by the court system. This procedure would provide flexibility and also reduce time and expense to the contractor. The new procedure would allow the contractor the option of appealing to an administrative forum, or appealing directly to the court system, if full judicial consideration was desired. The main advantages to this solution are (1) the "all disputes" provision which would encompass disputes not covered by contract terms--presently outside the jurisdiction of the ASBCA and (2) the contractor's option to select either the administrative process or the judicial process when filing an appeal. At present, the administrative Board process must be completed before the contractor can file an appeal in the court system. (2:123-124)

Conclusions

The solutions presented in this study discuss methods of improving the existing procedures and thereby restore effective resolution of disputes and appeals at minimum expense. Flexibility and responsiveness can be restored by:

(1) separating the roles of the contracting officer and providing Disputes Contracting Officers who would take juristiction of the contract when settlement negotiations breakdown, thereby eliminating the present dual role dilemma,

(2) establishing a series of small claims boards for claims under $25,000 as recommended by the Commission,

(3) revising the present Disputes clause to cover all disputes resulting "from the contract" for claims under $25,000 to provide options for the contractors.

Recommendations

In this author's opinion the following actions are recommended as a means of resolving the problems reviewed in this study.

(1) Revise policies, procedures and procurement regulations to provide improved guidance for contracting officers; establish a combination of appeals forums to provide the contractor with forum options in order to improve the responsiveness and flexibility of Government contract appeal procedures.

(2) Resolve the contracting officer's dual role dilemma by separating the roles and providing a separate Disputes Contracting Officer (DCO) for disputes and appeals.

(3) Provide additional appeals forums specifically oriented to resolving appeals involving $25,000 or less. The small claims boards recommended by the Commission should be established to fulfill this requirement. The small claims boards should operate with informal, fast, and inexpensive procedures. In addition, the Disputes clause should be revised to provide coverage of "all disputes" involving $25,000 or less. The boards would then decide all appeals below $25,000 in value unless the contractor chose to appeal directly to the court system.

(4) Provide various appeal options based on levels of due process, time, and expense. The contractor should be provided the flexibility to decide which appeals forum is best suited to his needs. The options recommended are small calims boards, ASBCA, and the court system.

The implementation of the above recommendations should fulfill the need for responsive administrative procedures for contract disputes and appeals.

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RELIABILITY INCENTIVES

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CONTRACTOR RISK ASSOCIATED WITH RELIABILITY IMPROVEMENT WARRANTY

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ABSTRACT

The results of a DoD tri-service-sponsored study to investigate contractor risks associated with reliability improvement warranties (RIW) are summarized in this paper. To provide appropriate background, the RIW and RIW/MTBF guarantee concepts are first reviewed. Key contractor-risk assessment models are developed and related to the issues of MTBF predictability and contractor warranty pricing.[1]

INTRODUCTION

A number of studies have indicated that military equipment is often less reliable than expected or specified and in some cases is significantly less reliable than comparable commercial equipment [2][8][9]. Poor reliability, of course, increases maintenance and logistic support costs and reduces operational readiness. To counter undesirable trends in support cost and readiness, long-term, comprehensive warranties are being applied in a number of military equipment procurements. The approach is known generally as the reliability improvement warranty (RIW).

There are many approaches for structuring RIW terms and conditions to cover various contingencies. Basically, all RIW contracts contain provisions for the equipment producer to assume responsibility for certain types of repair services for the warranted equipment over an extended period and to charge a fixed price for these services. One of the most frequently used variations is to include a provision whereby the contractor guarantees that a stated mean time between failures (MTBF) will be experienced by the equipment in the operating environment. If the guaranteed level is not met, the contractor must provide relief, such as instituting corrective action and supplying consignment spares until the MTBF improves. Inherent in all RIW contracts is an incentive for the manufacturer to design and produce reliable equipment. Profits are reduced with each unit returned for warranty service, and the contractor must determine how much to invest in design and production to achieve a product with a level of reliability that will maximize profits. In addition, if an unexpected reliability problem arises during the warranty period, the contractor must decide if he should make further investment to correct such a problem and thus reduce future warranty repair costs.

Although a number of warranty contracts have been negotiated with defense industry companies, considerable concern has been voiced about the risks inherent in the form of warranty currently being applied. The Council of Defense and Space Industries Association (CODSIA) has been the focal point for much of industry's concern with the degree of risk. In response to this concern, the Department of Defense has issued guidelines for warranty implementation that place particular emphasis on tailoring the terms of the RIW so that the rewards and risks to both government and industry are acceptable.[2] In addition, a tri-service contract was awarded to ARINC Research Corporation to examine risk issues, to determine their scope, and to suggest alternatives or modifications that would prevent excessive warranty risk.

This paper presents the major results of the study [4]. The primary RIW and MTBF guarantee risk factors that were identified, together with the suggested means for controlling such risks, are reviewed. Approaches for quantitative assessment of contractor risk are then described, with emphasis on reliability-prediction uncertainty. The conclusions and recommendations developed in this study are then summarized.

CONTROLLING RIW RISKS

The risks associated with RIW contractual commitments can be examined both quantitatively and qualitatively. The quantitative approach permits an objective assessment of the risks involved. The qualitative approach supports such assessment by addressing areas of uncertainty that cannot be studied quantitatively and by suggesting approaches to reducing the number of significant risk variables.

Our qualitative examination involved detailed discussions with experienced RIW contractors to gain an understanding of their misgivings, a review of industry's position

[1] Opinions expressed in this paper are those of the authors and do not necessarily represent those of the Department of Defense.

[2] Assistant Secretary of Defense (I&L) Memorandum, 16 September 1975, "Reliability Improvement Warranty (RIW) Guidelines".

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as represented by CODSIA,[3] and a study of past warranty contracts. We found that contractors are faced with both explicit and implicit risks. The former are directly associated with the contractor's entering into the warranty agreement and may include the following:

- The contractor cannot precisely determine the frequency of failure or the cost to repair.
- Equipment is subjected to unforeseen operational stresses, causing it to fail more frequently.
- By mishandling or tampering, military maintenance personnel may cause failures beyond contractor control.
- Increased equipment usage will increase exposure to failure.
- Slow government processing of reliability and maintainability Engineering Change Proposals (ECPs) will hamper the improvement process.
- The contractor may bid too low a price because of competitive pressures, optimistic reliability and maintainability estimates, or misinterpretation of provisions.
- The inflation rate may exceed planned levels, affecting labor, material, and overhaul costs.

The implied risks are less clearly defined. An RIW can affect sales and profit the contractor might realize on the equipment without an RIW. Additional contractor income has resulted from ECPs, spare part sales, and contract maintenance [12]. Although the RIW in itself represents additional sales, it may adversely affect the sales resulting from these sources. Conversely, it can be argued that the RIW will lead to a superior product that could ultimately result in more end-item sales. Contractors who desire to increase their share of the market, enhance the probability of follow-on awards, promote product-line growth, or foster public relations may choose to enter into a warranty agreement. In effect, a management decision is made to forego short-term profits for what are viewed as long-term benefits.

RIW RISK FACTORS

Some important factors related to these contractor risks are identified in Table 1, which also lists proposed risk-reduction approaches. Actions that might be taken to limit or preclude the risks are presented in the column headed "Risk-Reduction Approach". The factors presented in Table 1 constitute many of the risks likely to be enountered in RIW contracting; they represent current RIW knowledge. It is acknowledged that problems may arise in a given procurement that may be unique to the program or represent a set of new circumstances requiring the addition of new provisions. Finally, even with protective provisions, it is important that RIW and RIW/MTBF-guarantee is carefully applied only to situations in which there is reasonable expectations of achieving desired field performance.

CONTROLLING RISKS OF MTBF GUARANTEE

The inclusion of an MTBF guarantee in the RIW contract merits special attention. In most cases, the guaranteed-MTBF provision requires the contractor to provide consignment spares in the event operational MTBF does not meet a specified level. The contractor is also obligated to improve the equipment to resolve the reliability deficiency, and the government retains the consignment spares until such improvement is achieved. Careful consideration must be given to the additional risk associated with this potentially costly obligation.

The MTBF-guarantee provisions should not be included for the newer-technology items when there is great uncertainty about reliability prediction because of a limited data base on similar equipment. In addition, the provision requiring consignment spares may not be applicable if the production run does not coincide with the coverage period.

The definition and measurement of MTBF must be carefully stipulated and completely understood by both parties. In most cases, not all equipment returns are included in the calculation (e.g., excluded failures and unverified failures). Since military service data systems do not normally provide direct reporting of total operating time, clearly delineated procedures for for obtaining such data must be developed. The liabilities associated with the MTBF guarantee must be kept within reasonable limits. The following are suggested approaches:

- Provide a grace period before invoking the MTBF guarantee so that initial production and installation problems can be resolved.
- State a maximum number of consignment spares the contractor may have to provide and include a provision requiring timely government return of consignment spares as stipulated in the contract.
- Permit the contractor to offer, as new equipment, consignment spares that have been returned and refurbished
- If the equipment MTBF achieves the highest required level prior to contract termination, relieve the contractor of the need to demonstrate further compliance.

[3]Letters to Director, U.S. Army Procurement Research Office, July 1975; Chairman, Tri-Service Reliability and Support Incentives Group, December 1975; and Director of Procurement Policy, LGP, USAF, April 1976.

Table 1. Contractor RIW Risk Factors and Risk Reduction Approaches

Risk Factor	Risk Reduction Approach
Late notification of intention to use warranty	The intention to use warranty should be made known to the contractor as early as possible during engineering development so that he will have maximum opportunity to optimize his design.
Detailed government specification of item design	Functional specifications should be used to the maximum extent to permit design flexibility.
Application of RIW to advanced technology	Warranty may not be appropriate for completely revolutionary design. When applied to new technology, the program funding and schedule should allow for adequate reliability testing. A cost-sharing RIW agreement could be considered.
Reliability-prediction uncertainty	The government should specify only a minimum acceptable level of reliability. Operational and environmental data should be provided to the contractor. Adequate time and funding for necessary reliability testing should be included in the contract.
Unpredictability of inflation rates for long-term agreements	The warranty price should be tied to economic adjustment provisions to account for inflation.
Failures outside contractor control	Exclusions should be provided for such instances as acts of God, fire, explosion, submersion, flood, combat damage, aircraft crash, and unauthorized tampering by government personnel. Exclusions for mishandling should be carefully worded.
Large number of unverified failures ("test goods") returned to contractor	Contractual provisions should be made for sharing the costs of processing good returns.
Item usage rate not precisely known	The contract should provide for a price adjustment for significant variations in usage rate, or seek a cut-off on total operation time.
Data not supplied to contractor as required	Contract provisions should include government responsibilities for meeting data obligations in a timely manner. Contractor obligations for warranty performance may be related to receipt of applicable data.
Shipping destinations of warranted items may not be known at time of bidding	If there is significant uncertainty about shipping costs, the government should assume these costs.
Effect on turnaround time of events outside contractor control (e.g., strike, uneven flow of failed units)	Relief from turnaround-time obligation should be included as part of the contract.
Time-consuming procedures for ECP approval	Warranty provisions should provide for expeditious approval of ECPs, perhaps by automatic approval unless notification is given within a certain time limit.

- Do not invoke a guarantee on mean time between removals unless the product is very mature. Limits might be established on the "no trouble found" returns to provide for equitable risk sharing.

Common to all the factors discussed is that mechanisms to reduce risk can be evolved and included in the equipment specification or RIW contract. Review of existing RIW contracts also indicates that once risk-reduction approaches are established, they are applicable from contract to contract. This suggests that as experience is gained in RIW contracting, problems associated with many of the risk factors can be routinely resolved and eventually will not be considered major risk areas. The Department of Defense and the military services have established focal points for monitoring warranty contracting and implementation, which should provide the management continuity and control necessary to achieve this desired result.

QUANTITATIVE ANALYSIS OF RIW RISK

During the study, a number of approaches to quantifying warranty risk were developed. Risk quantification must consider the reasons why a contractor may propose or contract for an RIW:

- It is part of the RFP and the contractor has no choice if he is to be responsive.
- He believes that the RIW can provide additional profit on the contract.
- He believes that RIW is the "coming thing" and that the particular contract will serve as a good learning vehicle.
- He believes that the RIW will give him a competitive edge for future awards.

The first two reasons listed are related primarily to the contract under consideration, i.e., a short-term view, while the second two are related primarily to long-term considerations. This distinction is important because the risk and uncertainty aspects are viewed differently for the two cases. In the long-term case, the contractor may consider the RIW portion of the contract as an investment in that the knowledge, experience, and reputation gained will provide future returns that are not otherwise obtainable. In this long-term view, the potential outcomes and prior probabilities are not as likely to be developed; we therefore limit our initial

quantitative investigation of RIW risks to a particular contract. However, the conclusions drawn will incorporate longer-term aspects as appropriate.

WARRANTY COST AND PRICE MODELS

We will quantify risk in terms of profit on the RIW; for a short-term view, this is a natural risk variable. (The investigation of risks also addressed RIW/MTBF contract profits and total contract profits. These results are briefly summarized in a subsequent part of this paper.) Several models for warranty cost and price have been formulated [3][6], but for our analysis a simplified version will be used. Such a model for contractor warranty cost has the following form:

$$WC = FC + \lambda \times TOH \times CR \qquad (1)$$

where

- WC = contractor warranty cost over the warranty period
- FC = contractor fixed costs associated with the warranty
- TOH = total operate hours of all warranted equipment over the warranty period
- λ = average hourly failure rate of all warranted equipment over the warranty period
- CR = average contractor cost to repair a unit returned for warranty service

The simplifications and assumptions inherent in this model are quite extensive and should be noted: Costs include overhead factors but not profit; all future costs have been discounted as necessary. The failure rate, λ, is an average value that accounts for such factors as reliability growth, varying population sizes over the warranty period, and returns of good items. The repair cost includes the processing of both good units and failed units plus any anticipated modifications necessary to achieve acceptable reliability.

The warranty price model used is based on the cost model and has the following form:

$$WP = (FC_B + \lambda_B \times TOH_B \times CR_B)FW \qquad (2)$$

where the subscript B denotes a "bid" value for pricing. The factor FW is the loading applied to expected costs to yield the fee or profit. Therefore, FW will generally be greater than 1.0, and its value may very well be influenced by the contractor's view of his risks at the time of pricing.

WARRANTY PROFIT VARIANCE AND DISTRIBUTION

For further simplification, we will assume that the risks and uncertainties associated with the fixed-cost (FC) and total-operate-hour (TOH) factors are at a relatively minor level. The fixed costs are usually fairly well known and are usually small relative to the total cost. The TOH factor is, of course, important and is subject to wide variations, but most current RIW terms and conditions have adjustments or controls for undue variability.

If we make the further assumption that failure rate and repair cost are independently distributed, we can show that profit variance is expressed by the following equation:

$$\sigma_P^2 = (TOH)^2 \left(\sigma_\lambda^2\ \sigma_{CR}^2 + (E\lambda)^2\ \sigma_{CR}^2 + [E(CR)]^2\ \sigma_\lambda^2\right) \qquad (3)$$

where

- E = expected-value operator
- σ_P^2 = RIW profit variance
- σ_λ^2 = variance in field failure rate
- σ_{CR}^2 = variance in contractor warranty repair cost

For illustrative purposes, we now consider a "typical" warranty procurement. One thousand units with four-year warranty coverage are to be purchased. Each unit operates 50 hours per month and has an average MTBF over the warranty period of 500 hours ± 100 hours and an average repair cost of \$250 ± \$35. Assuming that the ranges of MTBF and repair cost represent ±3 standard deviations of a normal distribution, we use Equation 3 to calculate a profit variance of $\$1.03 \times 10^{10}$, or a standard deviation of \$101,500. A profit/loss probability range is estimated by the equation[4]

$$100p\%\ \text{profit/loss range} = EP \pm k_p \sigma_p \qquad (4)$$

where

- EP = expected profit
- k_p = standardized normal deviate associated with probability level p

If the contractor bids at the mean values of MTBF and repair costs and if fixed costs represent 20 percent of total repair costs (20 percent of \$1,200,000 = \$240,000), the total bid cost is \$1.44 million. Assuming a fee factor

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[4]If λ and CR are each normally distributed, the product cannot be exactly normal. However, from a variance viewpoint, the term $(TOH)^2(ECR)^2\sigma_\lambda^2$ will generally dominate, so that CR is relatively constant compared with variation in λ. If λ is normally distributed, the normality assumption for profit will be adequate.

of 1.13 (relatively high to cover RIW risks), the warranty price is $1,627,000 -- a targeted return on sales of 11.5 percent.

We can now apply Equation 4 to evaluate profit/loss ranges from a probabilistic viewpoint. For example, for a 95-percent probability level, the standardized normal deviate is about 2, so that the 95-percent profit range is $187,200 ± 2 ($101,500) = -$15,800 to $390,200. In terms of return on sales, this range converts to -1 percent to 24 percent. If we extend the analysis as shown [4], we can state that if the contractor bases his warranty price on a 500-hour MTBF and a targeted return on sales of 12.5 percent, he will have 95 percent assurance of earning at least a 5 percent return on sales if the expected MTBF ranges from 430 to 590 hours. The equivalent range for a break-even situation is about 395 hours to 675 hours.

In many respects, the example used is representative of a number of military warranty procurements. While the assumptions made or individual numbers chosen might be questioned, we do not believe that it can be argued strongly that order-of-magnitude errors are involved. The example shows that RIW risk is not likely to be a "bet your company" proposition, as some have claimed; however, it entails distinct risks not encountered in non-RIW procurements.

RETURN ON SALES AND MTBF VARIATION

We now consider risks associated with warranty pricing on the basis of return on sales (ROS) versus MTBF variation, where

$$ROS = \frac{\text{Profit}}{\text{RIW Price}}$$

We let θ_B represent the average MTBF at which the warranty was bid and θ_A represent the actual MTBF. It can be shown that the ratio of these MTBFs is related to the warranty pricing variables by the formula

$$\frac{\theta_A}{\theta_B} = \frac{(TOH)CR}{FW\,(1-ROS)\;[(TOH)\,(CR)+\theta_B FC]\;-\;\theta_B FC} \qquad (5)$$

From the contractor's point of view, the lower the ratio of θ_A to θ_B for fixed ROS, the better. Equation 5 shows that the MTBF ratio θ_A to θ_B increases as FW decreases or ROS increases, which is equivalent to stating that the warranty risk is proportional to target ROS and inversely proportional to FW. For the other terms, the picture is not as clear. For FW (1 - ROS) greater than 1.0, the MTBF ratio (and therefore the risk) increases with ROH and CR and it decreases with θ_B and FC. The relationships are reversed when FW (1 - ROS) is less than 1.0.

If we ascribe greater utility to not losing a large amount of money than to earning a larger than normal profit (a usual position for today's risk-averse corporate society), we are more interested in the case in which FW (1 - ROS) is greater than 1.0. For this case, a low-risk RIW would be a contract for equipment with low utilization (i.e., TOH), low repair cost, high MTBF level, and high relative fixed costs, and bid with a high fee factor. Similarly, a high-risk procurement is one for which the utilization and repair costs are high and the relative fixed costs, MTBF level, and fee factor are low.

ROS/MTBF RISK RELATIONSHIPS

We have developed three "generic" risk cases based on the foregoing relationships; they are described in Table 2. These cases help in developing the risk relationship between the MTBF ratio and return on sales.

Table 2. Case-Study Values

Risk	Quantity Procured	Hours per Month	Years of Warranty	Fixed Cost	Fee Factor*	Cost of Repair	Bid MTBF
Low	500	50	4	$100,000	1.20	100	1000
Medium	1000	50	4	200,000	1.15	200	500
High	5000	50	4	300,000	1.10	400	100

*It might be argued that the ordering of the fee factors should be reversed; e.g., a high-risk procurement should have a high fee factor. This is certainly true, but we are merely developing generic cases. Perhaps competitive factors "force" the contractor for the high-risk case to use a 1.10 factor, one of the reasons it becomes a high-risk case.

However, we are concerned only with a segment of the total risk picture; thus these generic references do not necessarily apply universally. As a simple example, low utilization is generally accompanied by low risk. However, if the utilization is low and the procurement is small, perhaps not enough items will be returned early enough in the program to detect correctable failure patterns. Therefore, the contractor may be forced to "live with" the low MTBF he initially provides, for it might not be cost-effective to implement an ECP after the warranty has been in force for some time. This situation was actually encountered during an Air Force gyro warranty program.

To show the relationships quantitatively, Figure 1 plots the ratio of actual MTBF to bid MTBF for three types of procurement tabulated in Table 2. Of course, for any ROS in the figure, the higher the risk, the closer the actual MTBF must be to the bid value. For example, to break even on the warranty (ROS = 0%), the ratios of actual MTBF to bid MTBF are .91, .85, and .73 for the high-, medium-, and low-risk cases, respectively.

If the three illustrative cases can be used as generic models for most RIW procurements, we can conclude that for a profit to be realized on RIW, the average MTBF over the warranty period

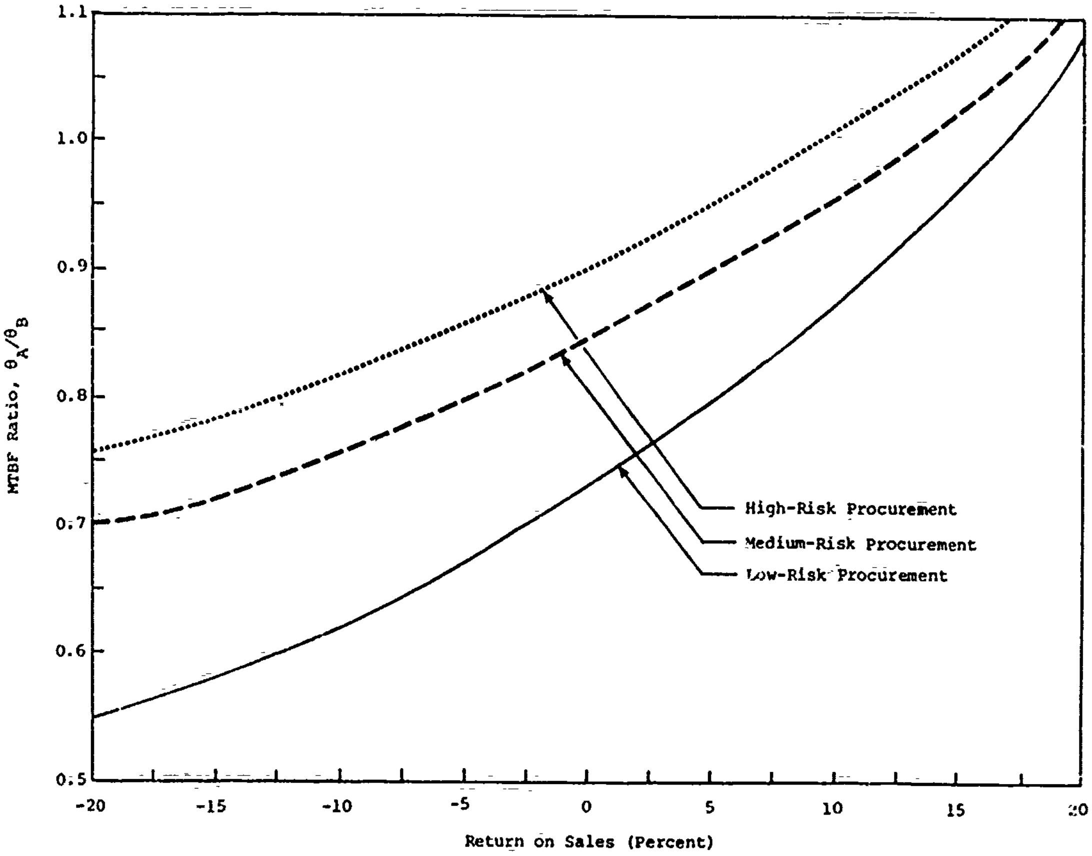

Figure 1. Relationship Between MTBF Ratio and RIW Return on Sales

should be at least 73 percent of the bid value for a low-risk procurement and at least 91 percent of the bid value for a high-risk procurement. For a 10 percent return on sales, the percentages for the low-risk and high-risk cases become 87 percent and 101 percent, respectively. It is shown in Reference 4 how the contractor may relate the fee factor (FW) to the MTBF ratio to provide further insight into warranty bidding risks. Figure 2 shows the relationship of FW to θ_A/θ_B for ROS levels of -10 percent, 0 percent, and 10 percent for the medium-risk procurement. It is noted that FW decreases at a decreasing rate as the MTBF ratio increases, a characteristic of the reciprocal relationship between RIW profit and MTBF.

MTBF GUARANTEE AND TOTAL CONTRACT RISKS

A number of other quantitative analyses were performed to include additional factors. When an MTBF guarantee is included in the RIW contract, the contractor risks increase with respect to MTBF variation. As an example, for one typical case examined, for a break-even result (warranty ROS = 0), actual MTBF must be about 85 percent of the bid value for an RIW alone, but it must be about 92 percent for the RIW/MTBF.

We also examined risks from a total contract viewpoint, where return on sales also includes hardware profit, which is assumed to be fixed. As expected, the field MTBF requirements appear must less severe from this viewpoint than they do when only RIW return on sales is considered. For example, for the medium-risk procurement, with a 10 percent hardware profit, achievement of a 7.5 percent total return on sales requires a ratio of actual MTBF to bid MTBF of about 0.73, as compared with a required ratio of 0.92 for only the RIW return on sales.

MTBF PREDICTABILITY

The ability to predict MTBF accurately has been the key issue in RIW risk. CODSIA, in a letter to the Air Force in 1976, stated:

"Until the hardware is tested in an operational environment, with typical operational

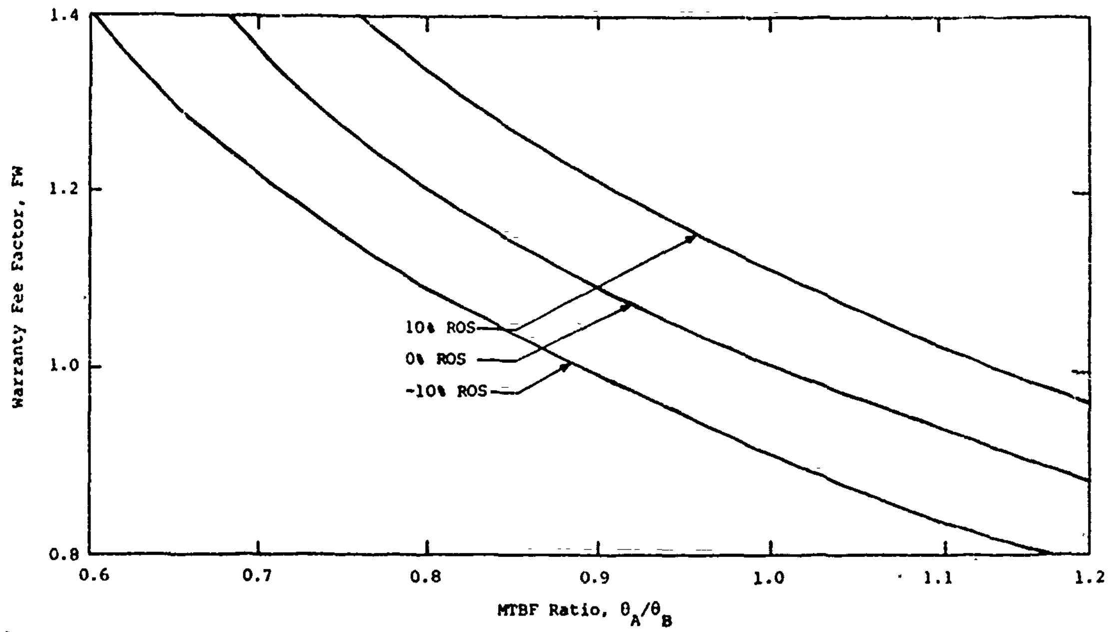

Figure 2. Warranty Fee Factors Versus MTBF Factors -- Medium-Risk Procurement

users, and in all planned vehicles/platforms, etc., reliability (the basis for a good RIW quote) is not 'reasonably predictable'".

We have shown in Figure 1 that for a medium-risk procurement, the actual MTBF must be at least 85 of the bid MTBF for the contractor to realize a positive return on sales from the RIW portion on the contract -- an accuracy requirement that appears on the surface to be well outside current prediction capabilities for a typical equipment program. However, for warranted equipment, we do not subscribe to this conclusion but believe that bid MTBF values and demonstrated MTBFs will be much closer to the field results than has been possible in the past.

The underlying reason for this belief is that under a warranty a contractor must place great emphasis on the operational reliability of his delivered equipment. Reliability prediction, test, analysis, and demonstration activities will no longer be performed simply because the government dictates them for government purposes. The manufacturing process will be more closely controlled to provide the maximum reliability inherent in the equipment. For example, there is evidence that because of a warranty commitment, contractors are increasing the number of inspection stations, establishing higher part-screening levels, and using longer burn-ins.

Reference 5 provides theoretical support that contractors have opportunity and strong incentive to correct reliability problems identified during the warranty period, and experience on a number of programs shows that the incentive is real [10].

Three additional factors are worth noting:

- As pointed out in Reference 11, the government's response to low field reliability has historically been to overspecify in hopes of achieving an improvement, which usually causes a gap between predicted or demonstrated MTBF and actual field MTBF. If current warranties are successful, this practice should diminish because contractors facing a long-term warranty will no longer automatically respond to unrealistic reliability requirements and the government will no longer have to resort to artificial devices in an attempt to meet minimum goals.
- It has been shown in a number of studies that a significant percentage of military equipment failures are maintenance-induced or maintenance-related [9]. Under warranty, units are usually sealed and the amount of military maintenance is limited. The result is a much lower factor for military maintenance handling, which should provide better correlation between predictions and field performance.
- While damage due to mishandling and abuse of warranted equipment may not differ from that for nonwarranted equipment, the failures that result from such causes are generally excluded from warranty coverage. Most

predictions and demonstrations do not account for such failures. From the contractor's risk viewpoint, however, the predictions will more closely reflect the field MTBF associated with his no-charge repair commitment than earlier predictions.

To support these conclusions, it is noted that for four equipments under warranty for which bid and field MTBFs are available, three had field MTBFs higher than the bid values. These four programs are summarized in Table 3. Data from References [8] [9] show that in the past only 20 of 112 equipments, or 18 percent, had MTBF ratios greater than 1.0. If 18 percent is taken as a population value for previously deployed equipment, there is less than 2 percent chance that the four warranted equipments have the same MTBF predictability as the population that has shown unfavorable MTBF ratios in the past.

Table 3. Summary of Four Military Warranties

Contract Element	Equipment			
	2171 Gyro	F-111 Gyro	Hydraulic Pump	TACAN
Contractor	Lear Siegler	Lear Siegler	Abex	Collins
Military Service	Navy	Air Force	Navy	Air Force
Contract Date	2/8/67	1/22/69	4/2/73	7/16/75
Competitive Aspect	Sole Source	Competitive Against Non-RIW Gyro	Sole Source	Competitive
Number of Equipments	833	128	250	Minimum 1000 Maximum 7586
Calendar Coverage Period	5 Years	5 Years	6 Years	4 Years
MTBF Guarantee	No	No	No	Yes
MTBF Ratio Expected to Field*	0.98	1.16	0.55	0.79
MTBF Goal Achieved*	Yes	No	Yes (to date)	Yes (to date)
Reference	1	7	10	3

*See text for amplification.

Of course, this small sample cannot be taken as final evidence that contractors under warranty can accurately estimate field MTBF, but the results are encouraging. One further point must be made. In all four cases the contractor has initiated no-cost ECPs to overcome some unexpected field reliability problem. Obviously, if those changes were expensive and if the contract price did not include a contingency for such action, achievement of a stated MTBF goal does not necessarily indicate that expected profit was earned, even if all other factors such as repair costs and fixed costs met pricing levels. There are no data on profit earned; however, except for the one case in which field MTBF was lower than expected, there is no evidence that contractor profit margins on the warranty were unacceptable. However, two of the remaining three programs are still in force; therefore, no firm conclusions are possible at this time.

CONCLUSIONS AND RECOMMENDATIONS

The basic conclusion drawn from the study is that a military warranty can be structured to share risk equitably. Further, warranties provide proper incentives to reasonably assure that equipment reliability objectives will be met. Achieved MTBF is the key variable in determining contractor risk under warranty. Quantitative risk models and early experience indicate that equipment MTBF under warranty can be controlled to provide contractors a reasonable profit expectation and that increased risk of loss is balanced to some extent by the greater opportunity for profit and (perhaps more important) by long-term benefits. These benefits include product-line growth, commercial spin-offs, and follow-on award opportunities. However, there is no doubt that if a contractor falls substantially short of the desired MTBF, considerable losses might be sustained, especially with an MTBF guarantee.

The risk analysis approaches developed in this study provide a simplified method for assessing contractor risk. Interviews with a number of RIW contractors indicate that assessment methods used to date have been mostly subjective, and this may have increased apprehensions about risk.

The recommendations encompass three areas: DoD policy, high-risk areas, and further research. Future DoD guidelines or directives should stress (1) that all warranties must be individually tailored to mitigate risks to both parties, (2) that MTBF requirements must be realistic in terms of what is actually needed and achievable, (3) that equipment development programs should provide adequate time and money for reliability testing and analyses, and (4) that an MTBF guarantee should not be used where considerable new or improved technology is to be procured.

With regard to high-risk cases, two courses of action are suggested:

- Investigate warranty plans with some form of cost sharing, possibly coupling this type of plan with a commitment that recognizes reliability growth from a risk reduction viewpoint [4].
- Study in greater detail the relationships between reliability predictions, reliability demonstration tests, and field results,

especially for warranty programs. Attempt to develop improved assessment methods that can be used to estimate expected reliability under warranty.

Additional research recommendations involve continued monitoring of current warranties regarding risk, study of government risk aspects, and development of an approach for providing positive incentives that balance the additional risk of an MTBF guarantee provision.

These recommended actions, individually or jointly, should assist in structuring warranty programs that equitably distribute attendant risks.

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A NEW LOOK AT WARRANTIES IN DEFENSE CONTRACTS

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INTRODUCTION

In August 1974, various parts of the Office of the Secretary of Defense (OSD) asked the three military services to begin trial uses of the Reliability Improvement Warranty (RIW), a contractual technique aimed at improving reliability of weapons systems and reducing their life-cycle costs [4]. Under an RIW, a contractor assumes responsibility on a fixed-price basis for repairing or replacing (as he sees fit) warranted units that fail during the warranted period. (A variation combines the warranty with a guarantee that obligates the contractor to take whatever steps are necessary to meet specific reliability levels.)

Although commercial firms have abundant experience with product warranties, the Department of Defense (DoD) has had only three completed warranty programs. Its current warranty activities are substantial, however. The Air Force, which is the leading service in this regard, has 17 items, including nine F-16 components, under a form of RIW. Depending on the number of options exercised, its expenditure for warranty coverage could reach $65 million (and the value of the items purchased under warranty could reach $500 million). Unfortunately, data on the outcomes of these programs will not be complete until the early 1980s. While awaiting the results, we have explored the RIW concept by evaluating commercial analogs, past DoD warranty experience, and the current tri-service RIW trial.[1]

COMMERCIAL WARRANTY EXPERIENCE

OSD's decision to promote RIWs was based in part on a high regard for commercial warranty experience. This study examined warranties in two commercial settings: consumer products and airline avionics.

Consumer product warranties have usually been either promotional or protective--i.e., they have either been marketing tools or devices to limit liability [2][5]. They have rarely improved product quality. Consumer product warranties have worked so poorly that the Congress recently empowered the Federal Trade Commission to monitor most aspects of warranty practices.

Consumer goods warranty experience does not justify optimistic expectations for RIWs, at least from the perspective of the military services.

Commercial airline avionics, which usually carry warranties, appear at first sight to be generally more reliable than similar equipment used by the military. However, there are too many differences in the commercial and military environments to credit the warranties with being the major cause of commercial products' better reliability. These differences extend to definitions, operating and support environments, missions requirements, and procedures for data collection and retention. In fact, the effect of the warranties is not well-understood by even the airlines; they have developed no standard by which to measure the cost-benefit derived from the warranties [1:B-4].

PAST DOD WARRANTY EXPERIENCE

There have been three items purchased by the military services under RIW-like warranties for which the period of coverage has ended. This section discusses those procurements.

The Navy's APN-154 Radar Transponder

The APN-154 is an airborne X-band radar transponder--a "beacon"--that extends the range of surface radar, allowing identification of specially equipped airborne targets. First produced in 1965 by United Telecontrol, it has been used on a variety of fixed-wing and rotary-wing aircraft. In 1973, a warranty went into effect on 218 units. Data collected under test conditions at the close of the warranty period indicated that the mean time between failures (MTBF) had increased almost four-fold from the pre-warranty level to 2025 hours, a seemingly striking success for the warranty application.

There is no evidence, however, to link the warranty and the reliability improvement. In fact, other factors more readily explain the improvement. For example, before the warranty, and independent of it, United Telecontrol undertook at its own initiative a company-funded study to develop longer-lived replacements for the local oscillator and magnetron assemblies. These two thermionic assemblies, produced before solid-state devices of sufficient reliability were affordable, were the major causes of earlier failure. The study produced a suitable solid-

[1] This paper is based on the authors' report, *Reliability Improvement Warranties for Military Procurement*, The Rand Corporation, R-2264-AF, December 1977. Views expressed in this paper are not necessarily shared by Rand or its research sponsors.

state replacement for the local oscillator design, requiring only minor power supply modification. Although the search for a solid state magnetron assembly was not successful, the contractor discovered that the magnetron's life could be extended by redesigning the existing cathode structure. United Telecontrol submitted an unsolicited proposal to the Navy to substitute the solid-state oscillator and modify the magnetron. When the changes were negotiated as an engineering change proposal to the existing production contract, provisions for warranty coverage were added.

In addition, several other changes were identified before the warranty entered the picture. Many of the earlier equipment failures were environmentally related. For example, in one case, the transponder was mounted adjacent to the jet exhaust tail cone. During normal flight and ground operation, the equipment temperature was maintained well within its limit, but in extended jet engine ground operation, as might occur during engine test or a prolonged taxi situation, the equipment temperature would rise more than 30°C above the maximum limit, causing equipment failure. Design changes in the heat sink and new component part selections provided satisfactory operation at the higher temperature and contributed to an unspecified increase in MTBF.

To the extent that the reliability improvement is traceable to such *pre-warranty* redesign and externally generated component technology advances, the warranty appears simply to have come along in time to receive the credit.

The Navy's 2171 Gyroscope

The 2171 gyroscope (the contractor's nomenclature) was initially designed and produced by Lear Siegler in the 1950s and was introduced into service with A-4 Skyhawks and F-4 Phantoms in the early 1960s. By 1967, there were about 3200 units, of various configurations, in the inventory. Using the data and experience gained during its maintenance of the gyro, Lear Siegler proposed a warranty for 800 of the 3200 fielded gyros. MTBF was expected to improve 30 percent, but a third of the increase was expected to result merely from updating the 800 units to the most reliable configuration then in the field. The results were favorable: The MTBF of the warranted gyros improved from 400 to 520 operating hours in three years (the MTBF of the non-warranted gyros improved to 442 hours during the same period).

Although some of the difference between the MTBFs of the warranted and non-warranted subpopulations cannot be attributed to the warranty (that part due to updating to the most reliable configuration), it would be unfair not to regard the warranty as a contributing factor. Two things must be considered, however, before generalizing from these results. First, the activities that probably led directly to the reliability improvement could have been promoted without the warranty. In this instance, Lear Siegler conducted a continuous test program, using laboratory units, which accounted for 50,000 hours of testing and provided data for corrective design change decisions. Second, whether the warranty approach saved the Navy money is also uncertain. A study prepared for the Naval Air Systems Command found that after a two-month contract extension designed to compensate for underutilization during the basic warranty period, the warranty costs were less than the probable costs of support without a warranty [1:31-32, App. A]. Independent recalculations by Rand revealed the differential to be much less than the Navy's calculation: in fact, after the period extension the warranty costs very slightly exceeded the predicted costs of the non-warranty alternative [3:48]. This difference is probably offset by the savings from reduced spares requirements made possible by the higher MTBF levels of the warranted units (about 23 percent fewer spares in the case of the 2171 gyro warranty population), whatever the cause, and by the greater operational readiness rates themselves.

The Air Force's F-111 Gyroscope

The F-111 gyroscope was originally designed in the early 1960s by General Electric specifically for use in the F-111. The first 534 units produced by General Electric experienced disappointingly low reliability, which prompted the Air Force to call for a new procurement in a competitive environment. The new contract, won by Lear Siegler in January 1969, contained a warranty provision. The MTBF of the warranted gyros peaked at 1214 operating hours, but later fell to 995 hours. The non-warranted gyros, which had an MTBF of 681 hours in 1966, achieved an MTBF of 749 hours.

The differences in reliability levels cannot be traced to the warranty. Lear Siegler incorporated no major design changes during the warranty period.[2] Several factors, other than measurement imprecision, may have accounted for the difference. The warranted units were produced by a new manufacturer at a later date and as a result of a *competitive* source selection: these changes may themselves have improved reliability. In addition, there was extensive additional failure mode testing conducted before the warranty period. As in the 2171 gyro program, this augmented test regimen could be duplicated even without a warranty.

[2]Lear Siegler did make one minor change: incorporation of a new bearing actuation to correct a directional gyro drift problem.

When the cost implications of the F-111 gyro warranty program are considered, two circumstances must be kept in mind:

- o The initial plans called for the purchase of 601 warranted units. The initial contract was influenced by cutbacks in the F-111 program and called for only 332 units. Additional revisions reduced the number to 128.

- o When the warranty period ended, the operating hours of the warranted units were about half the expected amount. The underutilization was due to recurrent groundings of the F-111 fleet and frequent delays in installations of the gyros. The warranty period began when the gyros were delivered to the Air Force; the F-111 prime contractor, General Dynamics, often installed them six months later.

The combination of these events had two important results. First, ultimate cost per operating hour of the warranty coverage was very high. Later contracts have used special price adjustment provisions to address this problem. A more troublesome result, one not addressed by new contractual clauses, is the deleterious effect on the contractor's motivation to make changes. The few units in the field and the low rate at which they were used meant that a representative failure distribution was not achieved until the warranty period was 80 percent complete. Lear Siegler justifiably chose not to make any investments in engineering improvement: its remaining period of responsibility for the reliability of its gyros was not very long, and the prospect for recoupment of its investment was reduced by the small number of units in the field.

Lessons from the Programs

Although examination of completed DoD warranty programs does not reveal conclusive evidence that the warranty was a major factor in the observed improvement, it does permit the following observations:

- o Modification aft · some operational use or appropriate operational testing is almost always desirable to take advantage of field experience and advances in component state of the art and can be promoted without a warranty.

- o Implied in the above statement is the worth of schedule flexibility to allow incorporation of test data in the subsequent development and production process.

- o To the extent that modification is envisioned or desired, the contractor should be involved in the initial overhaul and repair activities to improve his ability to formulate product improvements.

- o Because the prospect for reliability growth is dimmed by program quantity reduction and underutilizations, RIWs should not be applied to programs subject to extreme quantity or utilization uncertainty.

FINAL OBSERVATIONS: THE CURRENT TRIAL APPLICATIONS

Several aspects of current trial applications diminish the likelihood that they will yield conclusive evidence on the value of RIWs. Because an RIW is a collection of complex contractual terms, such an experiment can identify preferred contractual constructions. This opportunity may be lost if, as in the case of the present set of contracts, important terms and penalties vary widely and not in accordance with a conscious plan for evaluation [3:11-28]. Two other facts make the variation of terms disturbing: the absence of adequate "control" groups and conditions and the continued consideration of new applications. The design of the experiment should be improved by at least three actions:

- o *Reduce the variation in contractual terms and penalties.* A first step is the careful development of hypotheses about desirable constructions so that variations can be consciously and systematically devised to test them.

- o *Develop better control conditions.* The same difficulty in isolating the warranty as the cause of the reliability improvement in the completed DoD programs is likely to plague the analysis of current programs.

- o *Bound the experiment.* Rather than beginning new trial warranty programs for an indefinite period, the experiment, which has a discernible birthdate, should have a finite number of trial programs. This would permit better assessment of interim data and prompt final evaluation.

The experiment is also hampered by deficiencies in a number of associated methodologies. For example, both the contractor and the services have limited ability to price warranty and non-warranty alternatives in confidence. Methods for reliability measurement and prediction are similarly imprecise. Improvements in these areas would enhance selection, monitoring, and evaluation of warranty programs.

Evaluation of the warranty concept will be further complicated by the multiple, independent objectives that an RIW can serve and the

failure to establish priority among them. These objectives include:

- *Reliability improvement.* This objective is attained if the contractor is motivated to change his behavior so that the item he produces is more reliable.
- *Life-cycle cost reduction (cost shifting).* This objective is attained if the service "makes a good deal"--i.e., if the price of the warranty coverage is less than the price of alternative logistics support arrangements and if the warranty does not cause increases in acquisition cost or support cost after the warranty period (or during transition out of it).
- *Insurance (risk shifting).* This objective is attained if the service and the contractor execute a binding indemnification contract, enforceable in court.

Any one of these objectives can be attained without either of the others. That is (assuming the ability to establish cause and effect), a warranty might induce reliability improvement but increase life-cycle cost; or it might reduce life-cycle cost but have no effect on reliability; or it might fail either to reduce life-cycle cost or improve reliability but might be binding on the contractor to provide interim product support. The Department of Defense must agree on the priority of these objectives to create a framework for evaluating RIW data and formulating RIW policy.

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USAF TEST OF RELIABILITY IMPROVEMENT WARRANTIES

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INTRODUCTION

The Air Force is dedicated to improved military readiness and reduced Life Cycle Costs for its weapon systems and equipment. Reliability Improvement Warranty (RIW), under trial use in DOD, promises to both improve equipment readiness and drive down Life Cycle Costs. RIW establishes supplier responsibility for operational or "field" reliability, and maintainability of equipment. Its purpose is to motivate contractors to design and produce equipment with low failure rates and low repair costs in operational use. It uses the inherent incentives of a fixed price contract to harness the profit motive to bring about reliability growth and reduced repair costs during the long term warranty period.

The Air Force has made a major financial commitment to the RIW test. This paper provides an overview of the Air Force RIW program from a policy perspective. It includes a brief summary of each major application of RIW within the Air Force. The paper highlights the experience and lessons learned about RIW. It summarizes the results achieved with RIW and where increased emphasis is needed to bring the RIW trial to a successful conclusion.

The views expressed herein are strictly those of the author and do not necessarily represent the views of the U.S. Air Force.

AIR FORCE POLICY

One of the acquisition techniques which has been developed under the Life Cycle Cost policy umbrella is the RIW. The need to buy "affordable" military systems has been recognized and is being institutionalized in the Air Force. The Air Force is making a concerted effort to reduce costs, both acquisition and Operation and Support (O&S) costs. The Air Force is also intent on improving reliability to enhance military readiness. The focus of RIW is on both improved reliability and reduced Life Cycle Cost with particular emphasis on downstream O&S Costs.

The Air Force defines RIW as a provision in a fixed-price acquisition contract in which for a fixed price, (1) the contractor is provided with the monetary incentive to improve the production design and engineering of the equipment throughout the period of the warranty to enhance the field/operational reliability and maintainability of the system/equipment; and (2) the contractor agrees to repair or replace (within a specified turnaround time) all equipment that fail (subject to specified exclusions if applicable) during the period of the warranty.

The objective of an RIW is to motivate and provide an incentive to contractors to design and produce equipment which will have a low failure rate as well as low repair costs after failure due to field/operational use.

While there is logistics support associated with RIW, it is not used as a maintenance contract. Its thrust is directed toward reliability improvement in the form of increased inherent reliability for the hardware and reliability growth after the equipment is placed into operation in the field.

Based upon field experience and discussions with contractor people, we conclude that supplier concerns about field reliability have often been rhetorical. The traditional goal under Government contract has been Government acceptance, i.e., Government assumption of ownership of work tendered in performance of the contract. The act of acceptance transfers the risk to the Government. Unless reserved by a warranty or a certificate of conformance, the Government's right to reject after acceptance is limited exclusively to instances of latent defects, fraud, or gross mistakes amounting to fraud. Contractors have focused on passing required qualification demonstrations and production acceptance tests rather than good field performance. In addition, follow-on contracts for spares, service contracts and replacement parts to provide necessary operational support afford an opportunity through reduced reliability to increase sales to DOD.

ECONOMIC CONSIDERATIONS

RIW is intended to require contractors to share some degree of financial responsibility for field performance of their equipment. In this regard, Figure 1 depicts the inherent incentives of a fixed price contract without RIW while Figure 2 shows the inherent incentives of the same contract with an added RIW provision. Under a fixed price contract without RIW, a contractor, in theory, will maximize his profits delivering equipment with the lowest reliability that the Government will accept. The contractor has an inherent incentive to take actions to reduce production costs. Examples of cost reduction efforts include the elimination of certain in-process testing, speed up of the assembly process, and elimination of high reliability piece parts. Unfortunately, these actions may degrade the reliability of the product. Different incentives are at work under RIW. The contractor takes on the obligation to repair or replace all items that fail during the extended period of the warranty at a fixed price established

prior to commencement of the warranty period. Since the contractor has both a contractual obligation to produce the equipment and a contractual obligation to support the equipment during operation, ideally, he will be motivated to increase reliability to reduce his overall costs. In addition, subjecting an emerging system to a "test-analyze-and-fix" (TAF) process has proved to be a basic mechanism for achieving reliability growth. The RIW concept embodies this TAF concept.

RIW may be used to obtain a guaranteed Mean-Time-Between-Failure (MTBF). This feature serves as both an additional incentive to assure that a specified operational MTBF is achieved and as protection or "insurance" against short term asset shortages. An MTBF guarantee puts "teeth" into the RIW provision. Air Force applications which include the MTBF guarantee(s) require the contractor to provide consignment spares in the event of a low MTBF to prevent shortages of assets in the Air Force logistics system which result from the low MTBF. The MTBF guarantee feature also requires the contractor to perform engineering analysis of failed items and to make design changes required to achieve stated MTBF values. In the event that the low MTBF is not corrected at the end of the warranty period, the consignment spares become Government property at no additional cost to the Government.

An RIW may also include a guaranteed turnaround time (TAT). This feature provides an additional incentive to ensure prompt processing of failed units.

It is important to note that the Air Force approach in employing RIW and the MTBF guarantee, while resulting in a risk transfer from the Air Force to its RIW contractor, is intended to motivate contractors to deliver equipment with a higher inherent reliability than would otherwise have been provided. In addition, RIW provides a mechanism for achieving reliability growth. The interim results of applying RIW include both a contractor behavorial incentive and a risk transfer. The end results are intended to be both enhanced readiness and reduced Life Cycle Costs through improved reliability.

STATUS OF AIR FORCE APPLICATION OF RIW

The Air Force has made a major commitment to the RIW trial by applying RIW to 9 programs with a total RIW cost of about $65 million. It has been used on hardware costing about $500 million. These equipments covered by RIW are installed in both combat and support aircraft deployed worldwide.

Figure 3 lists both the "major" and "less than major" Air Force applications of RIW. The largest and most complex RIW application is for equipment on the F-16 Lightweight Fighter covered by RIW. The F-16 warranty commences in January 1979 and will cover nine equipments on 250 USAF fighters and 192 European fighters for a period of 4 years or 300,000 flying hours.

The second largest Air Force application of RIW is the ARN-118 TACAN, an airborne radio, used in navigation. This navigation set will ultimately be installed in about 85% of the Air Force fleet of combat and support aircraft. The warranty commenced in April 1976 and will end in March 1982. We have already seen sizable benefits from the ARN-118 TACAN, i.e., drastically reduced support costs and outstanding reliability growth.

The initial Operational Test and Evaluation for the ARN-118 TACAN was completed in April 1976. The test program included more than 50 equipments divided among three bases and four aircraft, namely, the T-38, B-52, KC-135, and F-111. The achieved level varied from 221 hours MTBF on the T-38 to 488 hours MTBF on the B-52/KC-135 with a composite reliability of 324 hours. This inherent reliability of the hardware is attributed, in part, to the RIW/MTBF guarantee. However, it is difficult to isolate and quantify that inherent reliability associated solely with the RIW/MTBF arrangement. It is likely that the field reliability of the TACAN would have been about 325 hours MTBF under the usual DoD practice of assuming all financial responsibility for field performance after acceptance of the hardware. Some twenty months after completion of IOT&E, the composite reliability has exceeded 1900 hours, i.e., a reliability growth of almost 1600 hours of field reliability improvement. Based upon discussions with people actually involved in the management of the ARN-118 TACAN program, it appears that this reliability growth is directly attributed to the RIW/MTBF guarantee.

Under the ARN-118 TACAN, the real incentives and workable mechanisms to grow real (field) reliability are being observed. For example, the Contractor has established a failure recurrence control program for the TACAN which includes the following elements:

Extended Burn-In for new equipment.

Burn-In returned equipment subsequent to repair.

Special isolated part testing.

Special parts screening, i.e., visual, electrical or mechanical.

Corrective action at source of piece parts.

Selective use high reliability parts.

Development of alternative sources of parts where expedient.

Identification of end equipment shipped with questionable parts and replace questionable parts on an attrition basis.

Review of design and where appropriate redesign circuits to remove critical characteristics.

It has been reported by contractor personnel that RIW has given them their first real opportunity, under a military contract, to determine for themselves the effect the total operating environment has on their product. They are now able to verify that field reliability growth can be made to occur.

Under the TACAN RIW program, the contractor has identified the following lessons learned:

Address and follow through on Reliability Critical items will result in improved field MTBFs.

A computerized failure data system is vital to timely recognition and correction of reliability problems.

A high degree of failure analysis capability at the contractor's facilities is essential for reliability improvement.

Close coordination among all disciplines at the contractor's facilities is required to resolve reliability problems.

Self-imposed testing such as Burn-In and Evaluation Sample Testing is needed to promote field reliability growth.

Another major Air Force application of RIW is the Carousel IV Inertial Navigation System (INS). The program contemplates installation of a dual INS set on the C-141 fleet, a single set on the KC-135 and a triple installation on the C-5 fleet. The need for a new INS evolved from an International Civil Aviation Organization requirement that all aircraft flying in the North Atlantic corridor be equipped with navigation equipment of accepted accuracy to meet reduced air lanes. The INS being procured, the Carousel IV, has been widely used in the commercial 747 aircraft and is covered by a commercial warranty similar to RIW. The contractor guaranteed an excellent reliability of 1178 hours, Mean-Time-Between-Failure, at a warranty cost which equates to about $1.41 per system operating hours. This support cost compares very favorably to approximately $10 per flying hour for other inertial navigation systems in use in the Air Force.

The other two major applications of RIW include the C-141 Altitude and Heading Reference System, (a third source of navigational inputs on the C-141) and a C-130 OMEGA Navigational set which will be installed on the entire C-130 fleet. The other 4 program using RIW are categorized as "less than major" since the RIW price is less than $1M.

A considerable amount of information is available for one of the "less than major" applications, namely, the F-111 Displacement Gyro. This program involved a multi-year buy of 332 gyros, however, only 128 units were actually procured. The contract did not contain MTBF or TAT guarantees. Results include:

The contractor made ten reliability and maintainability (R&M) design changes in the Gyro prior to and during production. These changes are directly attributable to the RIW provision. With those R&M improvements, it is believed that the RIW provided greater reliability than would have been obtained without the RIW.

The reliability decreased from approximately 1200 hours MTBF to approximately 1000 hours at the end of the warranty. No Reliability and Maintainability design improvements were made after delivery of the hardware. Reasons for the reduced reliability are unknown.

Specified Turnaround Time of 45 days was not met. The actual TAT for the warranty period averaged 90 days.

LESSONS LEARNED

A considerable amount of experience and lessons learned have been gained during the last three years about RIW Acquisition. Additional experience and lessons learned are now being gained on RIW Administration. We expect to obtain significant test data from both major and "less than major" applications of RIW. It is important to note, however, that our warranty performance experience is limited. A great deal of this information will become available during the next three years. However, we have gained enough experience to know that RIW and its application impacts far greater than originally expected.

Application of an RIW on a contract inherently implies that a tremendous amount of research, coordination, and soul searching has been done by both the contractor and the government. The contractor must understand what the government wants and be able to confidently assess the risks involved to respond with RIW proposals. The government must first define what it wants the RIW to achieve, i.e., higher reliability and/or lower life cycle cost. Once this is

done, impacts on the overall maintenance concept, manpower, data systems, and administration of the contract must be determined. Unfortunately, this is the area where we are discovering that we have major difficulties in implementation.

Implementation of an RIW automatically establishes the logistic concept (levels of maintenance, spares stockage, etc.) at least during the period that the RIW is in effect, i.e., organizational (remove and replace) and depot (contractor). Most RIW applications today state the Air Force desire to switch to an organic (in-house) maintenance capability at the termination of the RIW period. This concept requires early planning and coordination to insure that the manpower, support equipment, spare parts, training, and technical data is available to make this change. As we bring in the functional staffs that manage these areas, more and more questions surface, indicating that RIW is not as easy to apply and administer as originally thought. Presumably, we have always done all the necessary advanced planning and coordination required in all our past acquisition programs. The RIW has just highlighted the fact that maybe there are more interested players or more players who should be interested and brought in early in the conceptual stage of the acquisition process to assure a smooth, cost effective, reliable introduction of a new system into our operational inventory.

The most challenging phase of our RIW experience is in the administration. The magnitude of this task was underestimated when RIW was being developed in the Air Force in the 1973-1975 period of time. RIW demands a management organization, data, and an educated population of Air Force personnel who are involved in the daily processing of warranted components.

We have learned of the importance of an effective warranty reporting system. RIW requires a lot of data on the part of both the contractor and the USAF if it is to be effectively managed and evaluated. The data requirements become even more complex because each RIW program is unique, calling for slightly different approaches. Component serial number control, extensive use of Elasped Time Indicators (ETI), remove and install dates and test data findings seem to be the basic common denominator to measure the performance and guarantee commitments. We are conditioned to the fact that we must pay the contractor for data. However, there is a growing cadre of influential people within the Air Force who are concerned that we have already overburdened our technicians with data collection requirements, to the point where elimination of data is now a major movement. RIW, and its requirements, is running head on into this movement with the ultimate possibility that we may not be able to properly support or evaluate it. Changes to existing data systems and procedural directives needed to support RIW have been slow in coming or, in some cases, delayed. This is not to say that some progress has not been made.

Field failure notification to the contractor is being written into our RIW programs to insure prompt release of a serviceable replacement back to the field. This is done to hold down the number of spares in the pipeline and thus reduce costs. Originally, manual preparation of the message by base personnel was the method employed to satisfy the requirement. However, we quickly learned that normal base level communications capabilities were not responsive enough (administrative) nor completely reliable (human) to meet the provisions of the contract. Therefore, modification of the Air Force Standard Base Supply System is being done to automatically notify the RIW contractor when a failure is verified by the Air Force maintenance shop. This notification will advise the contractor which LRU failed, its serial number, the Air Force base which experienced the failure, and the shipping document number covering the reparable item being returned. In addition, the USAF Reparable Item Movement Control System directly routes the item to the contractor's designated repair facility with the appropriate "mark for" information. Applicable technical orders have been issued specifically outlining the level of maintenance authorized and the steps to be followed in verifying the equipment failure.

In another area, we are attempting to establish an independent data base, using existing Air Force data systems, in order to provide a parallel means of verifying guarantee provisions and evaluating the RIW concept itself. The success of this effort will depend on how well we can overcome the previously cited difficulties as well as the quality of data we receive. In all probability, we will be able to evaluate the concept and the benefits gained from RIW. Using the data base to verify key data cited in the contractor warranty reports may prove to be more elusive.

The most encompassing, and perhaps the most frustrating lesson we have learned about RIW is that in order to make it work, Air Force personnel involved in all levels of its management must be made aware of what RIW is, what part they play in it, and how their actions or decisions impact on others involved in the program.

A generic problem is delayed installation of warranted units. These delays are of great concern to the Air Force. Although there is some protection to the Government under the Operating Hours Adjustment provision, the inherent incentives of the RIW are eroded by warranted units which are idle. There may be another cost impact when old less reliable units with high support cost are being operated and maintained while the new highly reliable equipment remain not installed.

FINAL COMMENTS

We have learned that administration of a special warranty for equipments installed on a great variety of aircraft deployed world-wide is a challenging task. There is a need for special management emphasis, a great amount of data, and education of all levels of Air Force people who are involved in processing of warranted equipment and data. There is a need for special techniques to detect potential RIW problems. In this regard, the Air Force has established an independent automated data base, using existing Air Force Supply and Maintenance data systems, as a tool to use in administering the warranties. The Air Force has learned the value of a usage adjustment provision in the contract for both the contractor and the Government. Without such a provision, a contractor may be penalized by a wartime surge or reap an unearned windfall from reduced flying programs. The MTBF Guarantee is a powerful incentive which imposes additional risk on the contractor and complicates both the structuring of the contract and administration of the warranty. However, significant benefits have resulted from its use. Proper administration of the warranty is of utmost importance, otherwise, the promised benefits may be lost. Favorable results from RIW are being observed. The data from these demonstrations should be carefully studied before RIW is incorporated as a "business as usual" acquisition technique. During CY 1978, the Air Force will focus on the long term range planning needed to bring the trial of RIW to a successful conclusion.

FIGURE 1

COST TO PRODUCE WITHOUT RIW

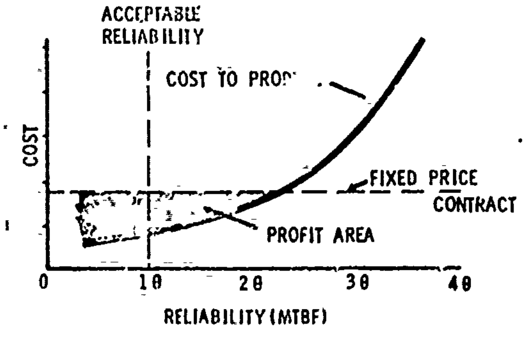

FIGURE 2

COST TO PRODUCE AND SUPPORT WITH RIW

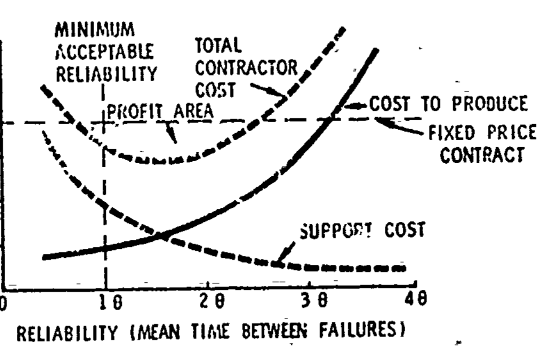

FIGURE 3

AIR FORCE APPLICATIONS OF RIW

PROGRAM	APPLICATION CATEGORY	GUARANTEE
ARN-118 TACAN	I	MTBF/TAT
C 141/KC-135 INS	I	MTBF/TAT
C-141 AHRS	I	MTBF/TAT
C-130 OMEGA NAV	I	MTBF/TAT
F-16 AIRCRAFT COMPONENTS	I	
FLIGHT CONTROL COMPUTER		TAT
RADAR ANTENNA		TAT
RADAR LOW POWER RF		TAT
RADAR DIGITAL SIGNAL PROCESSOR		TAT
RADAR COMPUTER		TAT
HEADS UP DISPLAY		TAT
NAVIGATION UNIT		TAT
RADAR TRANSMITTER		MTBF/TAT
HUD ELECTRONICS		MTBF/TAT
F-111 DISPLACEMENT GYRO	II	NONE
AVU-8 C/A AIRSPEED INDICATOR	II	NONE
C-130 HYDRAULIC PUMP	II	NONE
KLYSTRON ELECTRON TUBES	II	NONE

NOTE: CATAGORY I: MAJOR
II: LESS THAN MAJOR

PROFIT OR LIABILITY: CONTRACT INTENT VS. CONTENT *

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Key Words: Liability, Contracts, Failure Definition, Data Collection, Data Retention, Contract Law, Packaging.

Purpose-Abstract

This paper presents a relatively complex legal-reliability-liability case history. Two approximately equal parties signed a contract for the delivery of merchandise. Instead of continuing the relationship of a satisfied customer and profitable manufacturer, they became adversaries in a protacted legal proceeding which culminated in an out-of-court settlement reached just prior to trial. The agreement required the payment of a large portion of the total remuneration anticipated five years earlier when the contract was signed.

The content of this paper includes the contractual language used by the parties at bar. It also shows the product flow and relationship between supplier, manufacturer, customer, sales distribution organization, ultimate customer, repair and maintenance operations. The sequence of document exchange containing relevant information affecting the parties is discussed showing how it also contributed to the difficulty. The misconceptions and misinterpretations made by both parties to the litigation are explored. Both organizations involved in this action are competently staffed by highly qualified reliability and quality assurance engineers. Numerous in-house counsel and engineering-legal talent were employed in both organizations.

Marketing organizations compounded the problem by the overzealous puffing of product utility to contractual parties and to subsequent users. Product performance was oversold, but this had relatively little bearing on the basic outcome of the litigation between the two contractual parties. These two organizations were approximately of equal stature, both being well-known, nationally recognized manufacturers of military and commercial product.

We prepared this paper to establish an awareness of the pitfalls that can be encountered during all phases of the contract/product cycle. Some errors occurred in each of the following: negotiation, proposal, preliminary design, prototype analysis and engineering models. There was also inadequate preparation of facilities and personnel to handle, maintain or service the production quantities involved.

Background

The relationship between these organizations, divisions of much larger organizations, was originally one of partners! Perhaps this relationship was one of the underlying difficulties in the situation. What apparently occurred was that following what had been a long and profitable relationship both divisions were left with too large an operation and insufficient business. In casting about to find a suitable activity, the officers of Division A, Company A, saw a device in the laboratory of Division Z, Company Z. This was immediately recognized by A's officers as a product with enormous potential. It could be sold at a reasonable price. It had a potentially wide market. The service and installation operations would fit into the activities of Division B, Company A. If Company Z would make it, Company A would sell and service it. It was in Company A's collective market-mindedness that the product was the best thing since sliced bread was developed. It was, of course, necessary to enter into a contractual agreement, draw up specifications, start manufacture and delivery to the ultimate customer. Any device as big a drawing card as this thousand-dollar device was bound to draw competition, and they had to be prepared.

Difficulties abounded. No one at either Company A or Z had had very much experience with this product or with this type of device. Although a model existed, there were no detailed specifications or drawings. The actual reliability of the product was unknown. The mean-time-between-failure (MTBF) could only be determined when some of the design details became firm. The produce performance functions were stabilized after a few hundred units were in operation.

Company A originally wanted an 8000-hour MTBF. This requirement was based on:

a. Obtaining a reasonable profit.
b. Approximately 40 hours a week of us.

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c. Once every four years a service call would be required. (The less service required, the happier the customer.)
d. Early delivery and ease of installation.

Company A felt it was in excellent position to market the device successfully in many areas of the country. The volume was estimated to approach 100,000 units.

The specifications were drawn, and there seemed to be general agreement of what should be accomplished. Unfortunately neither division was sufficiently familiar with the product, its use, and the demands likely to be encountered. It was a "new" field to both adversaries, and as usual planning for the unknown proved treacherous.

The mutually-established specifications included:

1. Reliability Requirements
   The following shall be minimum requirements for the reliability of the device:
   Mean Life . . . . 5 years
   MTBF* . . . . 2,000 hours
   *MTBF shall be established by reliability analysis made by contractor and submitted to Company A for approval.

   Company A shall have the option to test these units for conformance to these reliability figures. Lack of conformance constitutes reason for rejection.

2. Quality Objective
   All components chosen shall be reviewed for quality and reliability by contractor.

   All proposed suppliers shall be investigated by contractor to establish the quality and reliability of past performance.

   Contractor's Quality Assurance Department shall audit manufacturing and machine assembly operations to insure workmanship meets the standards for commercial products.

   Contractor's Quali[illegible] Assurance Department shall audit all inspection and testing procedures to insure deliverable equipment meets specifications as set forth elsewhere within this document.

   Contractor's Quality Assurance Department shall review all field-returned devices prior to release for analysis and repair. All failure analysis and repair actions shall be monitored for failure trends. Areas which are repeated offenders shall receive corrective action.

3. Maintenance Objective

   Built-in self-checking features to minimize or eliminate the need for special field test equipment.

   Minimization of dust problems.

   Built-in endurance features to withstand operator abuse, misuse and mishandling of equipment.

   A minimum of operator-accessible controls and adjustments.

4. Warranty Agreement

   This agreement called for repair and/or replacement of all devices at Company Z's option upon receipt at Company Z. Company Z would pay the cost of shipment for the devices that were found to be "out-of-specification" on arrival at Company Z.

The Reliability requirements had been the basis of considerable discussion before the inclusion of the quoted 2000-hour MTBF item in the contract. The original desire on the part of Company A's engineers had been 8000 hours. The manufacturing company had consistently in discussions denied the ability of this product to exhibit an 8000-hour MTBF. The final commitment was a 2000-hour MTBF. Company Z grudgingly gave in to this figure, although feeling it was still too high. It should have been reduced further while the product was still under development. Nonetheless, Company A felt it had to have a product with a longer MTBF.

After the contract was signed and manufacturing had started, the reliability analysis was submitted on schedule. There was still no agreement between A and Z as to whether the reliability was adequate. It was contractually agreed that Company Z would establish a reliability test plan to be approved by Company A. Company A would establish the measured MTBF. If the units passed the test, Company Z would accept the test results as proof that the specified MTBF had been equalled or exceeded.

However, before the reliability tests were agreed upon, Company A began pressuring Z to deliver salable product built up to the initiation point of manufacture and delivery.

Whenever production precedes the testing for conformance, problems arise (as Murphy's Law infers). There were a considerable number of units received by Company A that were immediately returned to Z as "not working". Additional units were returned to Z which, it was alleged, had not been operable or satisfactory when installation was attempted.

Some units were removed after days or weeks of operation and returned to Z. In each case defects were claimed.

This traffic in units made A even more anxious to obtain units. They insisted that major

emphasis be on increasing the delivery rate rather than holding all shipments until corrections were made. The sales pressures kept building up for approximately nine months.

Visits of executives and engineers to expedite, correct, improve and rectify were becoming routine. The concept appears to have been fostered that a test to determine the reliability of the product was a luxury that neither A nor Z could afford at the moment. Thus the Reliability Test Plan was momentarily ignored.

After approximately 1500 units had been delivered, the available stock at Company A began to grow. Troubles were continuous and believed to be insurmountable. At this juncture, Company A issued a Stop Work Order while continuing to request that Z rebuild and repair "nonconforming" returned product. Six months later the contract was cancelled and Company A sued Company Z for losses and profits which should have materialized had the product been more suitable.

The primary claim in this suit was that commercial success had failed to materialize because of the failure of Company Z to deliver a product with adequate reliability. The allegations included an MTBF of less than 400 hours.

During the period of contractual relationships a reliability test plan had been submitted by Z which read essentially as follows:

The test had three criteria for termination. They are listed as Plans A, B, C. Sample-MTBF refers to the "Total-Test-Time" divided by the "number of failures during that time".

Plan A: There are five decision points (at 12, 16, 20, 24, 28 weeks). At each decision point, the sample-MTBF is compared to Table I. If the sample-MTBF is greater than the tabulated value, testing terminates and the test is passed; otherwise, testing continues.

Plan B: If the test is not passed in Plan A, discard the operating time and failures accumulated during the first 12 weeks (viz., before the first decision point). Calculate a new sample-MTBF. If it is greater than the tabulated value, the testing terminates and the test is passed; otherwise, the test data are re-evaluated.

Plan C: Use the total operating time and failures from Plan A. Subtract the number of failures in Table II from the actual failures and calculate a new sample-MTBF. If it is greater than 2000 hours, the test is passed; otherwise, the test is failed.

Table I

Termination Data for Plans A and B

(F) # of Failures	Critical MTBF (hours)	Critical Total-Test-Time (hours)
2 or less	---	8,095
3	2695	8,035
4	2460	9,840
5	2315	11,575
6	2215	13,290
7	2140	14,980
8	2085	16,680
9	2040	18,360
10 or more	2000	2,000 x F

Table II

Number of Failures to be Subtracted for Plan C

Total-Test-Time (hours)	No. of Failures to be Subtracted
Less than 12,000	1
12,000 to 26,000 inclusive	2
More than 26,000	3

The plan was unusual and was rejected by Company A on the basis that "the test plan was so devised that the product would eventually pass."

This was interpreted by many that regardless of the true MTBF of the product, the plan would eventually reach an Accept decision. Although discussions between Reliability personnel had taken place and many letters had been written to modify the plan, no formal contractual modification took place. This may have been due to the strained relationships which were now prevalent.

There were many imponderables. Correspondence from those associated with the project at both corporations indicated from initial field data estimates that the MTBF was 500 to 1500 hours. Naturally the higher figures came from Company Z. The litigation specifically raised these differences and were the cause of the suit according to Company A. Company Z initially agreed that this was the cause of the dispute. Later, during trial preparation, Company Z decided that poor marketing and intense technical competition were the causes of the decline in orders.

Discussion

At some point in every situation in which it appears that court action is imminent, both parties usually seek assistance. They obtain needed answers to questions that appear aca-

demic, but, as this paper will demonstrate, are not. Among the questions that arose in the instant litigation were:

1. What was the true field experience of the product?

2. What did the contract and specification really say?

3. How should the specification be interpreted?

4. What was the operating characteristic of the proposed and rejected reliability test plan?

If an agreement is made to deliver devices with an MTBF of 2000 Hours and the field experience is 200 to 300 hours, it is obvious that the product is grossly inadequate. If the field experience is 1500 hours to 1800 hours in the early life of the product, then one could expect the reliability growth to provide some improvement which combined with a few changes would provide for a reliability in later life of well in excess of 2000 hours.

Neither vendor nor vendee (Company Z or Company A respectively) had made an objective analysis of the actual operating data. Since the data had not been analyzed, the defendant was uncertain about the results presumably because the analysis might just prove the plaintiff's allegations. The defense position would then be untenable. When the need for such an analysis was presented, the defense was justifiably reluctant. Trial counsel finally prevailed upon defendant Company Z to allow a sample of the data to be taken for analysis.

MTBF Analysis

The data was obtained from two sources. One source was Company A's card record of each unit. A card existed for each serial-numbered unit delivered. The data on the card showed when the unit was received, its condition, its disposition depending on arrival condition, each date it was shipped hether to a site or to Company Z, each date nd location of insta ation and all movements of the device. Some devices were returned to Company A immediately. Many stayed in service for various periods of time. Some were removed and replaced, others removed, shipped and installed at other sites and some removed and returned to Company Z. Still others had been removed from service and returned to stock of Company A. In each case data was reasonably complete, and only one to two percent of the cards had to be discarded due to poor records.

The data of the vendor, Company Z, was also quite complete. It showed when each serial-numbered unit was first shipped and when it was returned. The data log showed whether or not the unit was operating within specifications when returned, and if repaired, whether it was repaired to update the unit or to correct a nonconformity.

Criteria Associated with MTBF

In making the analysis of Mean-Time-Between-Failures, a number of criteria were adopted by these writers during trial preparation. The contract and specification did not identify when or whether or not the device was to be counted as a failure. "Failure" was not defined. The adopted (for analytical purposes) criteria were:

1. A device received at Company A and returned to Company Z (vendor) without service time of one day or more was not considered to be a failure. It did not contribute any time to the total service time as it was not installed.

2. A device with service time at one site and subsequently removed and sent to another site was considered to have contributed to the total service hours but not to the number of failures (no evidence of failure).

3. A device which was returned from service at a site and which was returned to Company Z and found to be in conformity to specifications contributed to the total service hours but not to the number of failures as it was still operating satisfactorily.

4. Devices which were in service and subsequently returned to Company Z where they were found to require repair to satisfy specifications were counted as field failures. Their time in service was added to the total service hours.

These criteria are in conformity with the general practice of computing the Mean-Time-Between-Failures as the quotient of the total equipment operating hours divided by the number of failures occurring during the period. Failures before operation are not counted.

It had been established by Company A that service time would be based on 40 hours per week of use. There were, we are certain, instances where the device was powered twenty-four hours a day. Data supports this contention. Because of the large number of devices (1500) involved, Company Z reluctantly agreed to use the 40-hour week. The customer (Company A, Division A) maintained that the devices were actually exercised and [illegible] but a few minutes a day even though power was "ON" for longer periods. No meters or counters were installed on any devices in actual use. Nonetheless, the final agreement was that the

service life calculations would be based on a usage rate of 40 hours/week.

The first data analyzed consisted of Company Z's history of 20 devices. The MTBF calculated from the sample proved to be approximately 300 hours. This was an extremely low value. The analysts were not satisfied that the data were valid. The suspicion proved valuable as it was then learned that the selection of the devices had been made by Company Z on a nonrandom selection of the worst (most frequently returned) devices.

Using a random number table, twenty additional devices were selected from the remaining 1430 device population.

Adopting the same criteria, this group of twenty had an MTBF of more than 3000 hours. This highly significant lack of agreement between the two samples was found to have been caused by the nonrandom process used for the selection of the first group. Company Z thought that the analysts would find the most interesting data to analyze would be among the history records of the devices most frequently returned to the factory. The frequency of return of this first group of twenty exceeded the average by more than three times.

The data from Company A's card record which showed date of installation and "removal" showed substantially lower "in-operation" periods. The analysts combined these data (Company A and Z's records) to conduct the balance of the investigation.

Based on these data, the estimate of the MTBF (based on the forty-device sample) was found to exceed 2000 hours. This result so encouraged Company Z that it authorized the analysis of a totally random, unbiased sample of 60 devices from the total population. The results exceeded 2000 hours MTBF. The difference between the defense and plaintiff's approach was expected to be submitted to a jury for resolution of future problems.

Reliability Test Plan

Another defense investigation was simultaneously underway. The reliability test plan that had been proposed by Company Z indicated that the operating characteristic was essentially that shown in Figure 1. If the MTBF was 2000 hours, the probability of acceptance was 30%; if 1000 hours, 5%.

The operating characteristics changed slightly if the rate of accumulating operating time changed. It was not grossly different over the rates of 600 to 1400 total machine operating hours per week. The greatest changes seemed to occur if the MTBF was well below the specified value.

During the litigation there was much discussion concerning the merits of specifying a MTBF with or without a confidence level. If no confidence level or test procedure with an acceptance criteria is given, there is a serious question as to whether a specification actually exists. As in this case, the vendor may wish to provide a test plan that behaves like the well-known operation characteristics of Mil-STD-105D. If the true MTBF = 2000 hours, the test plan should accept the product with a probability of approximately 0.95.

The purchaser may, as in this case, hold for the concert that the test plan should accept the product readily if the true MTBF grossly exceeded 2000 hours. Under these conditions, the probability of acceptance would equal 0.1 if the true MTBF = 2000 hours. If the true MTBF = 3000 hours, then the probability of acceptance may exceed 0.8.

Based on this philosophy Company A was arguing that even if the MTBF of a sample proved to be 2000 hours, this was unacceptable.

Company A's Reliability Manual included definitions which were in essential agreement with the philosophy advanced by Company Z; yet in spite of these documents, Company A was willing to permit a court to decide the technical merits of the question. The results might have been interesting to the technical community.

At the negotiating state, a reliability test plan that would have satisfied both parties could have been devised. However, following this stage, cooperation is not anticipated. Each party then insists on the most advantageous interpretation for its organization.

Another phase of the contract that appeared to have been neglected was the definition of conformance. What could readily have been required is that on any sequence of shipments of N-devices, not more than "n" may be nonconforming to the extent that it need be returned to manufacturer for repair. As it was, both manufacturer and purchaser relied on a 100% sorting procedure to eliminate nonconforming product. This practice seldom works. It did not work in this instance.

It is difficult to decide exactly why the companies were unable to agree on a reliability test plan. Various opinions were offered:

a. The rejection of the Company Z prepared test plan was actually the result of trying to modify an earlier agreement.

b. The recipient and/or the writers of the test plan did not really have a true knowledge of the operating characteristics of the plan nor how it would be administered. The representative of the pur-

chaser rejected the plan believing that the plan would accept all product even if the devices were poorer than the desired 2000-hour MTBF.

c. The plan was unusual. It was therefore more politic to reject it than accept it. Company Z's Division "Reliability engineer" was unwilling to ask assistance from corporate personnel.

d. There was no real understanding what a 2000-hour MTBF really meant in terms of device performance. A numbers game was in operation.

These experiences and comments show the errors involved in specifying a reliability figure (MTBF) with neither a confidence limit nor a requirement of a demonstration procedure. Criteria for accepting or rejecting the product based on the results of tests is also necessary.

Shipping and Packaging and Related Damages

The product produced by Company Z and sold to Company A had to be shipped from Company Z to Company A. Data showed a minimum of visible and physical damage to the unit due to shipping. There was no physical evidence to demonstrate that the device suffered internal damage. There is, however, data that shows almost 30% of the devices were not "per specification" on receipt at a user's facility while less than 5% were so designated on receipt at Company Z. Company A used the device as a major element in a system. This component as a part of the system was leased to user organizations. Installations and service were provided by Company A field offices who handle the entire system.

The device went from Company Z via truck, plane and another truck to Company A. Company A checked for damage. Then, after temporary storage in a warehouse, Company A sent it via another sequence of truck, plane, truck to (a)

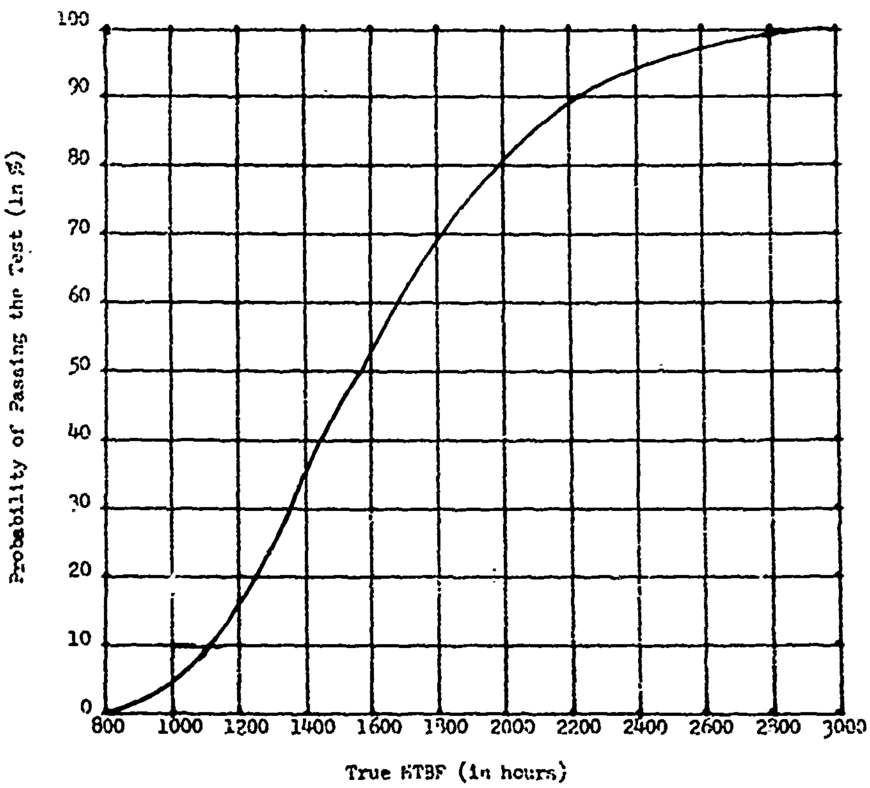

Figure 1

Typical Operating Characteristic of Test

(Total-Test-Time Accumulates at 1000 Hours Per Week)

its field office from which it was transferred via truck or car to user facility, or (b) directly to user facility. When a unit was transferred, it was handled in the same manner. When it was returned to Company A, it retraced the route.

The carton was designed per specification for delivery purposes, the shipment from Company Z to A. A large number of devices returned for service under the warranty were in original cartons. The carton designed for one sequence of shipment (truck, plane, truck) was actually being used for at least four sequences. There are no data and no ways of determining the deterioration rate per subsequent shipment in used cartons.

It would have been more appropriate to consider the entire sequence of handling from manufacturer to user in the design of the package rather than the assumed one-shipment philosophy employed. Where a package is expected to be used for multiple shipments and/or round trips, the package should provide appropriate strength and instructions (if any) that are to be observed for viable repeated use.

Purchaser's Product Assessment

During the time the litigation process was progressing, data were being analyzed and the test plan evaluated. Company A (the purchaser) had its engineers carefully review the device. We were advised that, after making minor revisions, the tested devices were consistently exceeding the 2000-hour MTBF requirement adopted by the analysts. As part of the court-approved settlement, Company A obtained the excess inventory left in Company Z's possession when the stop work order was invoked. Therefore, it may be assumed that the allegations of design non-compliance were not as critical as originally stipulated.

Failures - What are They and Who is Responsible

The question, when does a failure occur, was an important element in this litigation. The device must satisfy specifications; when it doesn't, it is a failure. However, given the routing and handling sequence of this device and the established contractual language, the defendant (Company Z) believed that the device had to arrive at its customer's facility in an operable ("within specification") condition. They had control over that phase of the delivery sequence. Company Z did not have control over unpacking, testing, opening the device, adjusting, closing, repacking, shipping, unpacking or installing the device after these many "handlings".

A real question arises as to what Company Z's true responsibility was when Company A's records showed internal shipping damage had contributed to "out-of-specification" arrivals. This question will probably never be answered since the litigation has been terminated.

To further compound the problem, the users were nontechnical. Every time an unexpected deviation appeared, the service department was called. Their instructions were clear and concise--remove and replace--satisfy the customer, when the device was under warranty. Since the warranty provisions were not enforced by Company Z, it meant that each device was handled as if it had still been under warranty.

All of Company A's field service offices were not equipped with test facilities. As a result, all units that were "suspected" to be out of specifications were sent to Company A's headquarters. Many removals were due to irregularities of power sources, operator errors and/or interface equipment. These devices were subsequently returned to Company Z for repair.

As noted above, some shifting between renting users was done to satisfy peak demands and other contractual problems between Company A and its customers.

In assessing MTBF, Company A counted every removal of a device for whatever cause as an "unscheduled" removal. This was interpreted as a "failure". This accounted for the disparity between the alleged 400 hours MTBF and the over 2000 hours MTBF calculated from the combined data sources using only failures that were confirmed when the device was tested by the manufacturer (Company Z).

A detailed agreement is needed before the questions arise. The agreement should contain answers to the following:

1. What is a "failure"?
2. When is it to be counted?
3. When failure occurs, are secondary failures the responsibility of the manufacturer?
4. How does a customer complaint become a failure? How is it to be confirmed?
5. Are all removals failures?
6. Should service personnel confirm device failures?
7. When warranty provisions apply, should purchaser of device be allowed, without penalty, to open the device; or does opening void his warranty?

Had most or all of these questions been de-

fined in the contract or in referenced documents, this litigation would probably have been avoided.

Conclusions

The lessons that can be learned from this financial debacle have undoubtedly been expensively learned by others in a similar fashion. Some of the lessons are:

1. Corporate procedures are designed to keep the company, its divisions and its personnel out of difficulty. They are usually wise rules, developed when pressures are absent and with a view toward avoiding and repeating past errors. Most of these corporate practices, devoted to the development of product and process, describe in minute detail what steps are to be taken in order to avoid problems. They are neither foolproof nor easy to follow. Nonetheless, ignoring these rules is an invitation to serious problems. By-passing the rules is almost certain to lead to a catastrophe.

2. All contractual agreements must be worked out before entering into a deal. Avoid the simplistic trust phrase: "Company 1 shall submit to Company 2 to provide a satisfactory plan for completion of a phase with "n" days after signing . . . ," unless penalties, stop work and contract cancellation can be invoked by <u>either</u> buyer or seller.

3. Satisfactory prototype(s) capable of demonstrating operational characteristics and reliability should be available, tested and approved <u>prior</u> to a production go-ahead.

4. A requirement for conformance to a specification is incomplete unless accompanied by a mutually agreeable or standard method of measuring the characteristic. When the product has satisfactorily completed the Standard Method of Measuring Performance, the result shall be accepted as proof of conformity. Tolerance limits are the rule for physical measurements, while confidence limits and test plans are needed for measurements involving time and decisions.

5. Accelerating production or delivery schedules are incompatible with the insistence on an improvement in workmanship and of the quality and/or reliability of the device.

6. The specification of a life characteristic MTBF neither includes nor replaces a specification for other characteristics of quality.

7. Define the criteria for acceptance.

8. Define what a failure is, when and where it becomes a failure, how it is to be counted or excluded from calculations of either criteria.

9. Define or describe shipping requirements for the device and the shipping container.

10. Reach agreement on how data will be retained and its availability (exchangeability) for analysis purposes.

Ignoring all or most of these warnings may result in claims against the manufacturer. A $30,000,000 lawsuit is an expensive way to find out that corporate procedures and policies were reasonably good after all.

Although there has been no total accounting of the amount spent in this litigation, the authors estimate that each spent considerably more than $500,000 to prepare their portion of the case. The detail contained herein is taken from an actual case history which ended in an out-of-court settlement where the defendant (Company Z) paid the plaintiff in cash and inventory a figure greater than $1,250,000.

For obvious reasons, no references or acknowledgements are shown which would identify the parties at bar.

Biographies

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Mr. Jacobs actively serves industry as consultant in Reliability, Quality Control and Product Liability Prevention methods since 1968. He is also an Adjunct Associate Professor of Industrial Engineering at New Jersey Institute of Technology, Newark, New Jersey. He was previously employed by Westinghouse Electric Corporation, Radio Corporation of America and Sylvania Electric Corporation. He is a graduate of Syracuse University where he earned a B.S. (1949) and an M.S. (1952) in Industrial Engineering.

He is editor and author of a text being prepared, "Minimizing Product Liability--A Systems Approach"; Past Vice President and current Secretary of the Reliability Group of the Institute of Electrical and Electronics Engineers; International Secretary--Reliability Committee (TC 56) of the International Electrotechnical Commission and Vice Chairman of the E-40 Technical Aspects of Product Liability of the American Society for Testing Materials. A member of the American Society of Safety Engineers and the American Society of Mechanical Engineers, he organized and chaired the first eight Product Liability Prevention

Conferences. He is an ASQC Fellow and is an ASQC Certified Quality and Reliability Engineer. A Certified Safety Professional, he holds Professional Engineering Licenses from California and New Jersey.

Mr. Jacobs received the Annual Electronics Division (ASQC) Award for service and contribution to the fields of Reliability and Quality Control and the Division in January 1972. He has presented over 200 papers and conducted seminars throughout the world at industrial, education, governmental and society functions.

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Mr. Mundel is a consultant specializing in quality control, reliability, liability litigation and management systems serving government and industry. He holds a B.S.E.E. from Cooper Union Institute of Technology, an M.S. in Engineering from the University of Michigan. He is a registered Professional Engineer in New York State and the State of New Jersey.

Prior to this, Mr. Mundel was Vice President of Sonotone Corporation with responsibility for the introduction of many products and procedures which contributed to organizational success and growth. Some of these are described in the more than 40 papers published on Sampling Procedures, Narrow Limit Gaging, Reliability, Quality Control, Vendor-Vendee Relations, Hearing Aids, Electro-Acoustic Transducers, Batteries for Aircraft and Satellites, Product Liability Prevention and Recall.

He is a frequent lecturer at industrial, educational and scientific society meetings, a Fellow of the American Society for Quality Control (past Vice President and member of the Board of Directors), a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and is certified as a Quality Engineer and a Reliability Engineer by the American Society for Quality Control.

He currently serves as Chairman of the American National Standards Institute Z-1 Committee on Quality Assurance, Consultant to the American Society for Quality Control Standards Committee (past Chairman) and the United States Representative to the International Organization for Standardization, Technical Committee on Application of Statistical Methods (ISO/TC 69) and a member of the Product Liability Prevention (PLP) Conference Management Committee.

GRANTS AND ASSISTANCE MANAGEMENT

PROCEDURE FOR ASSESSMENT OF SCIENTIFIC SOURCES (PASS)

Mervin F. Shreve, Code AIR-215C
Naval Air Systems Command, Washington, D.C. 20361

INTRODUCTION

NAVAIR's materials research and exploratory development program consists of approximately $5 million annual expenditures. This program is done approximately 50% in Navy laboratories and 50% with universities, industrial laboratories, and private research organizations. The characteristic size of each contract with industry is between $50,000 and $100,000 and is normally for a one (1) year period. Thus there are about fifty (50) contracts each year, approximately 1/4 of which are new starts and the remaining 3/4 consisting of extensions of on-going work.

HISTORY

In the early 1960's a review of the Materials R&D Program contracting practice was made and the following facts were observed:

a. A very large percentage of the contracts were based upon "unsolicited" proposals from a limited number of offerors.

b. Known sources were quite limited in number, i.e., only those with which contract monitors were familiar.

c. When a diligent attempt was made to include all of the identifiable potential sources, their number was large, i.e., over 20. This meant that when over twenty (20) complete proposals (cost and technical) were received in response to an individual solicitation, the combined cost to the offerors for preparation of responses were equal to or greater than the value of the one resultant contract. It was recognized that these costs must, in some manner, be passed to the Government.

STUDIES AND DISCUSSIONS

Study and discussion of ways to improve the contracting practice made against a background of DOD, ASN(R&D) and ASFR policies, guidance, and instructions led to the following conclusions:

a. In general, the NAVAIR engineers were unable, without consultation with outside scientific experts, to write a set of optimum requirements for specific material R&D contracts in detail adequate to permit competitive procurement on a fully defined program.

b. Consultation with outside experts could not be extended to all sources due to time and manpower constraint and such consultation was a signal to those consulted that an "unsolicited" proposal might be well received.

c. There was no assurance that the ultimate source was the highest technically competent source.

d. NAVAIR needed a procedure where, (1) all interested sources could be informed regarding planned "Material R&D Programs", (2) interested sources could respond with technical detail thereby assisting NAVAIR engineers in fully defining the technical program, and (3) assurance could be gained that the most technically competent source was identified.

PASS SYSTEM

The PASS system was developed to meet the needs set forth above and is set forth as follows:

a. Cognizant technical personnel will prepare a memorandum for AIR-02E1. This memorandum will set forth (1) the objective of the material R&D program to be accomplished, (2) the estimated level of effort required, (3) a list of the information required to be included in the response, (4) how the response will be used by NAVAIR, and (5) the time when response is due in NAVAIR.

b. AIR-02E1 will prepare, using the aforementioned memorandum, a synopsis for publication in the Sources Sought section of the Department of Commerce "Commerce Business Daily" (CBD).

c. Cognizant technical personnel, upon receipt of the responses to the CBD, will perform an analysis to determine which response to send with a Procurement Request (PR) to the contract group. The analysis will address (1) the techncial merit of the selected approach, (2) the experience of the selected source, (3) the qualifications of the personnel who would perform the work, and (4) the areas of original thinking and unique ideas presented by the selected source which cannot be divulged to other sources. If the selected source is not the only source found to be fully qualified thechnically or presents no unique ideas that are the product of

original thinking then this system shall not be pursued.

d. Contract Specialist upon receipt of a PR with a selected CBD response will (1) use the CBD response as a base for negotiation and request, as required, any additional information required for contracting with that source, (2) prepare Request for Synopsis Memorandum to AIR-02E1 setting forth under additional information, the following statement: "The Naval Air Systems Command intends to negotiate a contract with the above firm. This firm submitted, in response to an Advance Sources Sought Synopsis in the Commerce Business Daily a technical response containing unique ideas which were the product of original thinking and which cannot be divulged to other sources or was the only response found to be fully qualified technically," and (3) negotiate and finalize a contract with the selected source.

e. AIR-02E1 will prepare, using the Request for Synopsis Memorandum, a synopsis for publication in CBD.

LIMITATIONS TO PASS SYSTEM

The PASS System shall not be used if:

a. the "Material R&D Program" can be specified, by NAVAIR without outside input, in detail sufficient for establishing a competitive solicitation with optimum established requirements and criteria for source selection can be established;

b. other than scientific manpower directed toward a material R&D objective is to be procured;

c. the resultant contract exceeds $100K.

RESULTS

a. Interested source are informed.

b. Expensive technical and cost proposals from all interested sources not required.

c. Highest technical competent source selected.

d. Negotiations and contracting limited to one source.

SAMPLE

Research and Development Sources Sought Synopsis

DIRECTIONALLY SOLIDIFIED SUPERALLOYS (NON EUTECTIC)

The Naval Air Systems Command is planning the procurement of one and a quarter man-years of effort in a scientific study of non-eutectic superalloys suitable for directional solidification processing into high temperature aircraft gas turbine blading. Interest is in investigating compositions which have the potential for highest possible material temperatures consistent with acceptable balance of characteristics desirable in turbine blading, such as oxidation-sulfidation resistance, ductility, intermediate temperature properties, and fabricability. Interested sources are invited to submit the following information in concise form: (1) The proposed approach to accomplish the task and the scientific rationale on which the approach is based in detail; (2) The identity of the scientific personnel who would conduct the investigations and the qualifications they and their organization have for undertaking this work; and (3) An estimate of the cost of a one and a quarter man-year effort. Responses will be evaluated to determine which response (1) contains the highest technical merit, (2) evaluates to be the highest technically competent source, and (3) evaluates to be the most desirable response to pursue, technical, cost and other factors considered. The Naval Air Systems Command will not divulge your response with anyone outside of the Government. Since responses will contain unique ideas and will be the product of original thinking, only the source selected for contracting with will be contacted as a result of this request. The information shall be furnished to the Commander, Naval Air Systems Command, Department of the Navy, Washington, D. C. 20361, Attn: AIR-   , within four weeks of the publication of this notice. Naval Air Systems Command Synopsis No. _____________.

CONTRACTING UNDER GRANTS: THE NEED TO DEFINE THE FEDERAL ROLE

Robert D. Newton

THE ISSUE

The issue of contracting under federal grants needs attention. Policy decisions affecting this issue are made without adequate public discussion of their implications. The issue involves operational and legal questions. It also involves political and theoretical questions of the proper federal and non-federal roles and responsibilities in our federal system. The basic questions which need exploring are those of accountability and responsibility. This paper will explore some aspects of the basic questions in the hope of clarifying the federal role in contracting under grants.

FEDERAL PROCUREMENT-RELATED INVOLVEMENT

Procurement-related involvement by federal agencies is occurring in grant programs. The Department of Transportation and the Environmental Protection Agency are substantially involved in grant transactions, having significant contracting under them. A good case can be made that large dollar-amount, one-time procurements for complex items or systems under grants require federal involvement or federal control. This involvement or control is justified in the name of accountability for the expenditure of federal funds.

FEDERAL SYSTEMS INVOLVEMENT

The promulgation of procurement standards in Attachment "O" to OMB Circulars A-102 and A-110, and the development by an interagency task group, under the auspices of the Office of Federal Procurement Policy in OMB, of a detailed procurement standard relying on concepts and distinctions drawn from the federal procurement system are outcomes of federal concern for adequate procurement and project management under grants. Such standards, by virtue of establishing a procurement system's requirement in the grants areas, will encourage, if not require, all federal agencies to be more involved in grantees' projects and activities. Moreover, because the proposed procurement standard is for a system based explicitly on concepts from the federal system, it will encourage further federal involvement in the establishment and use of recipient procurement systems.

GAO INVOLVEMENT

Along with the development of procurement standards and increased federal agency involvement procurements under grants, the General Accounting Office has established a protest or complaint procedure under which it will advise on protests on contracting under federal grants.[1] This has happened because of the lack of procurement experience and case law in the states. In providing advice, GAO draws on federal experience in procurement. With that comes the application of the principles of federal procurement law. To that extent, the GAO protest procedure, like federal executive agency involvement, predisposes us in the direction of making the federal procurement system a national system.

WHAT SHOULD THE FEDERAL ROLE BE?

There is more at issue here than procurement activities under grants. Federal involvement in grantee third party relationships will affect the prime relationships between the federal agencies and grantees. The type of federal involvement that is occurring should improve the management of some activities and projects. But unless the federal role is clearly understood, defined, and circumscribed, the result is likely to be more federal involvement, not only in the types of projects and activities in which it is desirable, but also in other types of assistance projects and activities, the conduct or management of which have traditionally been the responsibility of recipients. The latter can happen because the complex and novel projects or activities in which federal intervention may be desirable will not be systematically distinguished from other types of assistance projects or activities in which it may not be desirable. By affecting all grantee procurement, federal procurement-related involvement has implications for all grant-type assistance relationships.

The issue involves the need to define the federal role with respect to federal procurement-related involvement and the use of federal procurement standards. We have described the current situation. The question that needs answer is what should the federal role be with respect to contracting under grants? To answer this question it is necessary to consider the broader question of the federal role in grant programs. Unless the latter question is dealt with, no realistic answer to the former is possible.

THE PROLIFERATION OF FEDERAL GRANT REQUIREMENTS

The proliferation of federal grant programs has been accompanied by a proliferation of federal grant requirements. It is these requirements or "strings" which most exasperate grantees. There are several reasons for the proliferation of grant requirements. The proliferation of

*National Science Foundation. The views expressed herein are those of the author and not necessarily those of the National Science Foundation.

novel or complex federal programs has of itself required the development of new standards which tend to draw the federal agencies into new interactions with grantees. The complexity of projects has required federal participation. Construction, demonstration, applied research, and development often call for federal operational involvement during performance. In addition, congressional generation of new public policy provisions, which are now generally applied to grants as well as contracts, require federal involvement to implement them. Finally, there is another reason more difficult to handle, for the proliferation of requirements: the emphasis on accountability for the expenditure of federal funds.

FROM A FEDERAL PERSPECTIVE: ACCOUNTABILITY

From the perspective of the federal bureaucrat, the proliferation of requirements is plausible. Congress creates a program. Rules are established to implement it. A problem occurs in its implementation. Something must be done about it. A clause is prepared elaborating requirements and providing for federal review or approval. Federal involvement is thereby increased. It is increased to insure that the bureaucrats, of which the author is one have met their responsibilities for the expenditure of federal funds. Inasmuch as the personnel in the federal agencies are criticized by Congress or GAO when something goes awry, do bureaucrats have any choice but to attach the strings necessary to insure accountability?

FROM A RECIPIENT PERSPECTIVE: INTERVENTION

The reverse side of the coin of accountability, from a recipient perspective, is "intervention." State and local recipients of federal grants have for some while deplored federal "intervention." But it is not they alone. In a recent report to the members of the Board of Overseers, the President of Harvard University repeatedly used the term "intervention" to describe his perception of the federal role in the relationships of the university with federal agencies. He notes that:

> the rising tide of government intervention has begun to provoke serious concern from many colleges and universities . . . In a few short years, universities have been encumbered with a formidable body of regulations, some of which seem unnecessary and most of which cause confusion, administrative expense, and red tape. If this process continues, higher education will almost certainly lose some of the independence, the flexibility, and the diversity that have helped it to flourish in the past.(2)

Recipients of federal grant awards tend to feel helpless, victims of an avalanche of requirements they can do little to hold back.

INVOLVEMENT OR INTERVENTION?

A significant reason why involvement is increasingly perceived as intervention is that the newer requirements involve the establishment of various kinds of systems or programs to implement them. Establishing an affirmative action program is more complicated than following wage rates established by Davis-Bacon Act. Because systems requirements are federal requirements, federal officials are the experts on the hows and whys of compliance. Recipient bureaucracies are built to match federal bureaucracies. The supposed simple procurement standard in Attachment "O" of OMB Circulars A 102 and A-110 and the proposed detailed elaboration of it are good examples of incipient "systems intervention." To take a simple illustration, the basic standard requires competition. But the concept of competition in the federal procurement experience is complex. It requires the elaboration of detailed exceptions for permitting "competitive negotiation." It also involves the notion of the "competitive range," which has required a series of GAO decisions to interpret and define. If a federally imposed standard is mandatory, and if GAO holds that requirements once imposed must be enforced(3) grant recipients will procure in a fashion different from that implied by the federal system only at their peril(4)

Twenty-five years ago some institutions of higher education were concerned that accepting federal grants for research would eventually lead to federal control of higher education. This argument was used in opposing the creation of the National Science Foundation(5) Since that time it has generally been felt that the original concerns were unwarranted. Federal support and grantee control are compatible. If so, why are the same types of concerns being expressed with increasing frequency now? Is what was feared beginning to happen? And happening with the best of intentions as a result of pressures on the federal agencies for accountability for the expenditure of "federal funds." Federal "involvement" in grantee systems may be becoming federal "intervention."

THE GRANT HAS BECOME A LESS MEANINGFUL ALTERNATIVE

Our federal system is a division of responsibilities among federal and non-federal entities. In establishing and implementing pro-

curement and assistance relationships we make role and responsibility decisions. When we elect to use grants rather than contracts, we are in theory making choices which have federalism implications and which in the aggregate should be very significant. In practice they tend not to be very significant because in federal/non-federal relationships the term "grant" has lost much of its original meaning. Grants are now used for purposes different from those for which they were originally used. Instead of clarifying respective federal/non-federal roles, the use of grants often confuses them. A grant has become a less meaningful alternative. It has, thus, become easier to proliferate federal requirements and encourage federal intervention in the name of accountability. Role decisions are made ad hoc and unsystematically.

To be true to our federal system we should be asking: "How do we decide who should be doing what and why?" The individual federal bureaucrat is in no position to ask that question systematically. The problem needs institutional attention. Unless we can find ways to maintain the integrity of the federal grant, it will, like the DOD airplane which was continually modified to accommodate new technical needs to the point it was too heavy to fly, become a cumbersome anachronism. That could have unfortunate effects on non-federal responsibilities in our federal system.

THE ARGUMENT FOR "ACTIVE" OR "TOTAL" FEDERAL ACCOUNTABILITY

The use of grants to serve substantially different purposes is responsible for most of the present confusion. Precisely because of this confusion, the use of grants for inappropriate purposes has been accompanied by new assertions of the need for federal accountability.(6) The argument for active federal accountability is, as I read it, first, that because funds pass through the federal exchequer, the federal agencies are responsible for their expenditure; and, second, the agencies must impose requirements on grantees to assure accountability. Once that is done, GAO holds that the agencies must actively enforce the requirements.

The first part of the argument, that because funds pass through the federal exchequer, the federal agencies are responsible for their expenditure, does not wash. It is a principle that need not be applied to all transactions or relationships. It is not applied to direct payments to individuals or to general revenue sharing. Overseeing the disbursement of federal funds in one type of federal/non-federal relationship is one thing. It does not follow that the same principle needs to be applied to all federal/non-federal relationships or to all recipient disbursements.

The second part of the argument, that because the federal agencies are accountable for the expenditure of public funds in assistance programs, they must actively assure that those funds are spent effectively, begs the question of what federal responsibility should be. That argument is made without effective rebuttal because no clear, viable operational alternative to federal involvement is being articulated.

FEDERAL ROLES MUST BE ALTERNATIVELY DEFINED

The philosophy of federal procurement is clear. It rests on ultimate federal control of the acceptability of a product or result. The philosophy of federal grants is less clear. It rests on recipient responsibility in keeping with federal standards. But it has been confused during the past two decades. In many grant programs enacted in the 1960s Congress asserted a direct national interest in a large range of functions and activities. The Congress intended that the federal agencies intervene in projects and activities to assist in achieving specified national objectives. The Congress realized that this intervention would entail some federal supervision and control.(7) However, neither the Congress nor the Executive has given systematic attention to what federal/non-federal roles and responsibilities should be, namely, who should be doing what and why. There is no federal assistance system in terms of which systematic decisions can be made on federal intervention or involvement or the lack of it.(8) If we are to do an adequate job of managing the projects which require federal involvement, while reducing red tape and unnecessary strings on those that do not, we must systematically allow for a passive or reduced federal role in some cases and an active or increased federal role in others. This is necessary to reduce the confusion and waste that exist.

TYPES OF ACCOUNTABILITY

Until we are able to specify when federal involvement or federal control should occur and clearly distinguish assistance projects in which either of these relationships is desired traditional grant projects and activities, and procurement relationships, the danger that federal involvement or control will proliferate to satisfy the pressures which incline the federal agencies in that direction will remain. Most assistance relationships do not require substantial federal involvement. Few require federal control. When involvement or control is required, specific agency decisions should

be required. We need a practical way of differentiating between the federal control and federal involvement required in some projects and programs and the absence of federal involvement or control characteristic of the traditional grant relationship. If we are to systematically manage federal involvement and control, we need to define them.

We need a range of types of accountability. We have full federal accountability in federal procurement in which the federal agency assumes responsibility for specifying a product or service and assuring that it is produced and delivered or provided satisfactorily. A similar type of federal accountability or control can or should be arranged to serve some federal assistance purposes or objectives. In some assistance projects and activities we should have shared accountability in which federal officials and recipient officials participate in assuring that projects or activities are successful. And in most assistance projects and activities we should have grantee accountability in which the grantee is given clear responsibility for performance in keeping with minimum federal standards.

Alternative types of accountability, expressed in terms of procurement relationships and three types of assistance relationships, can be defined as shown on page 6.[9]

These same alternatives can be expressed diagrammatically and related to agency purposes and methods of obtaining proposals as shown on page 7.

IMPLICATIONS

The management alternatives or types of accountability we have outlined are workable[10] and provide an answer to the question of what the federal role should be with respect to contracting under federal grants.[11] Federal involvement and control should occur in some cases but not in others. Procurement-related involvement should occur only in assistance contract or cooperative agreement relationships and in a way consistent with the relationships established. It should not occur under grants, which should entail federal delegation or devolvement of decision-making authority to grantees.

Recognition of alternative federal and non-federal roles also suggests a way to handle procurement systems involvement. Systems involvement is not transaction- or project-oriented and cannot be introduced selectively. It is total or indiscriminate. It is involvement at an institutional level.[12] It is inconsistent with the little or no involvement appropriate for grant projects and programs. To introduce procurement standards for all grants or other assistance agreements, as is done in A-102 and A-110, is improper because it is not selective, but indiscriminate. Federal/non-federal relationships on systems questions relating to the management of assistance projects and activities should be established only at an institutional level, not at the project or activity level. There should, for example, be federal executive branch negotiations on systems questions with representatives of institutions or aggregates of institutions. That would tend to insure parity of negotiating strength so that federal systems involvement would occur as technical assistance to improve non-federal systems that are used in achieving national objectives.

We have concluded that to rationalize procurement-related federal involvement there is a need to institute a system of alternative federal and non-federal roles reflecting alternative federal procurement and assistance relationships. Such a system will permit and require controlling involvement. Federal involvement does not need to become intervention, the unnecessary proliferation of federal requirements. Accountability can be defined differentially, reducing pressure for federal officials to intervene. Pressure to intervene has increased because the grant alternative is not well defined. The grant has become operationally meaningless in many federal agencies. That in turn increases pressures for accountability. This vicious circle can be broken. It can be broken by defining the grant in a way that requires separating projects and programs requiring significant federal involvement from those which do not. This requires institutional change, not just tinkering or ad hoc adjustments by some federal agencies. The Congress and the Executive must take the initiative. Until they do, confusion such as that over procurement-related involvement will remain.

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(1) Notice given in Federal Register September 12, 1975.

(2) Derek Bok, "Harvard University: The President's Report, 1974-1975," delivered January 10, 1976, pp. 4 and 22-23.

(3) See, for example, GAO Decision B-185790, July 9, 1976, Griffin Construction Company which states "... unless a grantor takes such actions as circumstances indicate are necessary to assure compliance with conditions it imposes upon grantees, there will be no guarantee that what the agency requires to carry out congressional purposes will be met."

(4) The practical problem here may be one of how to transmit the essence of the federal system to recipients of federal awards without the paperwork and bureaucracy that accompany the federal system.

(5) See Milton Lomask, A Minor Miracle, An Informal History of the National Science Foundation, Ch. 3, "Old Fears and New Ideas," Washington, D. C., GPO, 1976.

(6) See Thomas J. Madden, Providing an Adequate Remedy for Disappointed Contractors Under Federal Grants-in-Aid to States and Units of Local Government, Federal Bar Journal, Vol. 34 (1975), pp. 201-228.

(7) See James L. Sundquist and David W. Davis, Making Federalism Work, Washington, D.C., The Brookings Institution, 1969.

(8) A framework for a federal "grants" system was proposed by the U.S. Commission on Government Procurement in its Report of the Commission on Government Procurement, Vol. 3, Part F, "Federal Grant-Type Assistance Programs" (Washington, D.C., GPO, December 1972). The basic Procurement Commission grant concepts are discussed in Robert D. Newton, "Towards an Understanding of Federal Assistance," Public Administration Review, Vol. 35, No. 4 (July/August 1975), pp. 372-377, and elaborated in Administrative Federalism, to be published in Public Administration Review.

(9) Legislation embodying these concepts was introduced by Congressman Frank Horton, Chairman of the U.S. Commission on Federal Paperwork, on January 6, 1977. See Cong. Chiles, Glenn, Hathaway, McIntyre, Muskie, Nunn, Percy, Roth and Weicker on January 25, 1977. See Cong. Rec. for January 25, 1977, p. E-53. Identical legislation was passed by the 94th Congress in October, 1976, but was vetoed by President Ford on the premise that the concepts or some variation of them could be implemented administratively.

(10) The Energy Research and Development Administration and the National Science Foundation have proposed to implement these concepts.

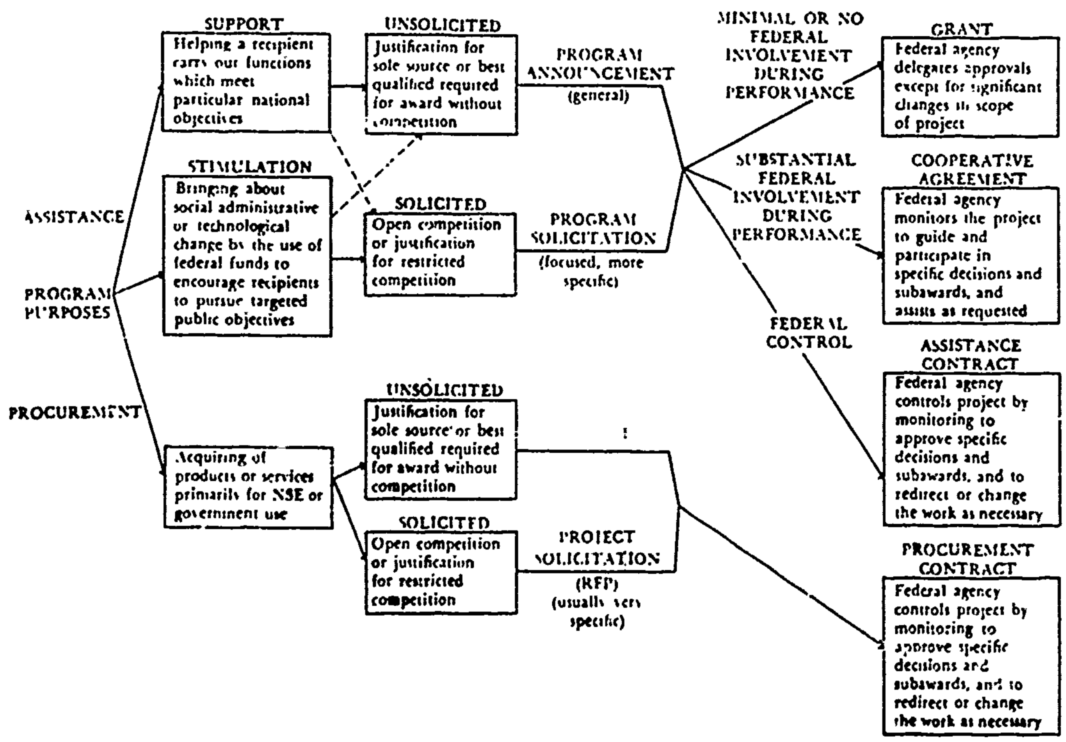
(11) The approach suggested also has implications for grantee financial systems and the federal audit role. Should grantees be required to have the same types of cost accounting systems as industrial contractors? Should the federal audit role be the same for procurement contracts, assistance contracts, cooperative agreements and grants? Should there be during performance evaluative and financial audit of contract, cooperative agreement and assistance contract projects and activities and after-the-fact or delegation of audit on grants with negotiations on needed systems conducted at an institutional level?

(12) Of course a contractor with many federal contracts may prefer systems approval in lieu of the review and approval of individual transactions. The important point with respect to federal assistance is that that choice should be a recipient choice and not federally imposed as is now the case.

Program Management Alternatives

	PROCUREMENT CONTRACT	ASSISTANCE CONTRACT	COOPERATIVE AGREEMENT	GRANT
FEDERAL ROLE	1. "Purchaser"	2. "Manager" of some assistance relationships	3. "Partner" or "Active Supporter"	4. "Patron" or "Passive Supporter"
PRIMARY RESPONSIBILITY	Federal	Federal	Shared	Recipient
TYPE OF FEDERAL INVOLVEMENT	Whatever involvement is necessary consistent with Federal Procurement Regulations	Whatever involvement is necessary	Substantial management or technical involvement during performance on specific decisions, subawards, provision of guidance or technical assistance, or collaboration	Federal delegation or devolvement of decisions and approvals
RIGHT TO REDIRECT OR CHANGE WITHIN SCOPE	Unilateral Federal right to change or redirect	Unilateral Federal right to change or redirect	Recipient right to change or redirect, subject to Federal advice, assistance, persuasion, or concurrence	Recipient right to change or redirect

Methods of Obtaining Proposals and Program Management Alternatives



THE RELATIONSHIP BETWEEN THE FEDERAL GRANT AND COOPERATIVE AGREEMENT ACT AND THE FEDERAL ACQUISITION ACT

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INTRODUCTION

This article addresses the relationship between the Federal Grant and Cooperative Agreement Act and the Federal Acquisition Act of 1977 (S.1264) and implications of the Federal Grant and Cooperative Agreement Act of 1977 for the promotion of technological innovation.

THE FEDERAL GRANT AND COOPERATIVE AGREEMENT ACT (P.L. 95-224)

The "Federal Grant and Cooperative Agreement Act of 1977" has now become law. It provides disciplined criteria for use of contracts, grants, and cooperative agreements and provides for an OMB Study to determine the feasibility of providing guidance in the field of Federal assistance. It also provides OMB authority to establish additional criteria for the use and application of administrative instruments in different situations.

THE FEDERAL ACQUISITION ACT OF 1977 (S.1264)

The "Federal Acquisition Act of 1977," S.1264, if enacted, will provide a totally new, single statutory basis for the total acquisition process. If it did this alone, it would be a major achievement. However, it does much more than this. Since it emphasizes policy rather than procedural detail, it provides broad latitude to the Office of Federal Procurement Policy in OMB to improvise, to test new procedures and techniques in the acquisition process. Thus, it provides a new range of options or opportunities for program implementation within the acquisition process.

As a result, the Federal Acquisition Act broadens the utility of the contract as an administrative instrument to reflect desired roles and relationships of parties. Under the Federal Acquisition Act of 1977, if enacted, one could use a wide variety of contracting devices under that Act or if the element of assistance is involved, can go to the use of a cooperative agreement, with a wholly different set of accountability features and controls, or can go the grant route where the flavor of the assistance transaction contemplates little Federal involvement.

Agencies which now use contracts to achieve some of the purposes that are better suited for cooperative agreements now have a broader choice of program implementing options as a result of the enactment of the Federal Grant and Cooperative Agreement Act.

John H. Young of the Office of Technology Assessment, in his article entitled "Implications of the Federal Grant and Cooperative Agreement Act of 1977 for the Applications of R&D in the Civil Sector," beautifully articulates the range of new options under that statute, namely P.L. 95-224 (S.431).

He points out that the major advances in research and development occurred through the acquisition process in fields such as the Atomic Energy, and the Space Program, and that a number of projects were developed to promote the transfer of the new technology from those programs to the civil sector. However, the success of these technology transfer programs has been limited insofar as utilization of such technology in meeting research and development needs of the civil sector.

His article addresses the subject of research and development to promote technological innovation in the civil sector, that is, bring to practical application and commercial utilization, new technology needed to meet civil sector needs.

OBTAINING THE COMMITMENT OF PRIVATE RESOURCES

Young points out that one of the primary distinguishing features of trying to introduce technological innovation into practical civil sector applications, is the requirement that organizations in the private sector commit skills, management, resources and funds to accomplishment of the objective. Their willingness to do that depends upon motivations inherent in our competitive system, and therefore, the techniques used by the Federal Government for research and development in the acquisition process to meet "Government" needs is not suitable for and cannot be applied to bringing technological innovation into actual commercial application in the civil sector.

Young points out that the Federal Government's role in promoting to actual fruition technological innovation in the civil sector, is more nearly that of "partner" and the arrangement between the Federal Government and non-Federal parties is more in the nature of a joint venture. Consequently, many of the elements of accountability and controls in contracting under the acquisition process would have no realistic application or appeal under a joint venture arrangement. This is because the private sector member must utilize the mechanisms that he employs on a day-to-day basis in making decisions and in managing projects within the entrepreneurial framework.

He illustrates this point by reference to the possible different treatment that patent rights may require in connection with a cooperative agreement to promote civil sector objectives such as the development of commercially feasible energy process. The unilateral right to change direction or to terminate would take on a less acceptable flavor, he points out, in the environment of a joint enterprise. This was also pointed out in an article by the ERDA Deputy General Counsel, Leonard Rawicz, described in the concept paper on cooperative agreements, elsewhere in this Symposium.

John Young also points out one distinguishing feature of innovation goals for the private sector. The fact that the non-Federal parties who have the capacity and incentive to deliver the goods and services from which the public will benefit, will be involved in the delivery of such goods and services long after Federal support and involvement comes to an end. And, of course that is the very purpose of the Federal involvement, to promote the commercial utilization and the ultimate disengagement of the Federal Government from participation in the project.

The Young article further points out that the Federal Grant and Cooperative Agreement Act expresses no policy preference as to whether there should be more or less Federal involvement or control in assistance relationships. Rather, it establishes a framework of relationships that requires explicit delineation of Federal and non-Federal roles and responsibilities.

GUIDELINES FOR CONGRESS IN REVIEWING PROGRAM IMPLEMENTATION

Young's discussion is particularly useful in that it provides guidelines for the Congress to consider in reviewing activities of executive agencies for the purpose of determining whether the provisions of the Federal Grant and Cooperative Agreement Act are being effectively implemented.

For example, he poses several questions for the purpose of such guidelines: Is the distinction clearly drawn between (1) generating new knowledge to expand the range of technological options, and (2) fostering specific technological innovations? This question would, of course, disclose whether an agency has given full thought to the roles and relationships and the type of administrative instrument, and the accountability and controls necessary to bring about technological innovation and its commercial utilization in the private sector (as distinguished from simply developing new technology and leaving it hanging).

Another guideline question he poses for Congressional utilization is: Are the Federal and non-Federal roles and responsibilities appropriate to assistance relationships reflected in the use of alternative legal instruments? Here he points out that assistance relationships, such as under a cooperative agreement, imply a cooperative effort in achieving a common goal; that such goals lie beyond the limited period of Federal involvement and support. The introduction of the cooperative agreement, now available on a Government-wide basis, provides a means for sharing responsibility with non-Federal parties while retaining the degree of Federal involvement necessary to achieve public policy objectives.

Another question posed by Young for utilization by Congress in the review of implementation of the Federal Grant and Cooperative Agreement Act: Is the potential of a uniform Government-wide framework for systematically learning which program inputs achieve the desired program outputs, being fully exploited by executive agencies?

This question, for example, would also be utilized by OMB in learning on a Government-wide institutional basis, which arrangements work and which do not, and therefore offers the opportunity for providing guidance in delineating roles and responsibilities and the proper administrative instruments to reflect those roles and responsibilities.

CONCEPTS IN THE APPLICATION OF ASSISTANCE DOLLARS TO PROFIT-MAKING ORGANIZATIONS

Another area of discussion in the Young paper is the fact that under the Federal Grant and Cooperative Agreement Act, Federal assistance may be provided to private sector profit-making organizations. A good illustration of this would be the use of cooperative agreements on demonstration projects where the organizations able to bring such projects to commercial utilization would normally be profit-making organizations.

He points out the need to assure that the distribution of such assistance is on an equitable and competitive basis; that such assistance must be provided in such manner as to equitably and competitively achieve the public goals at the same time that the private profit-making organization is in pursuit of its normal profit objective.

Young uses an intriguing scenario in which the Treasury Department entered into various kinds of transactions including both procurements and cooperative agreements to achieve a civil sector objective, in this case, the development of computer-aided coding programs to handle bearer bond indebtedness by cities. This was done essentially through analysis of why the ordinary market forces in the entrepreneurial system itself were not producing the needed technology and then constructing the environment in which the entrepreneurial sector was motivated to achieve this objective through catalytic use of some R&D funds of the Treasury Department.

Young points out that one of the key problems here is to take a civil sector R&D problem, such as a State or city problem, and get it placed on the R&D agenda of a Federal agency. These civil sector problems tend to fall between the crevices of the mission mandates of agencies. He points out that this situation may turn out to be a fundamental limitation on the effectiveness of the Federal R&D policy tool.

CATALYTIC ROLE OF THE FEDERAL ACQUISITION ACT IN PROMOTING TECHNOLOGICAL INNOVATION

At this point, it is interesting to observe, under the proposed "Federal Acquisition Act," that there would now be introduced a basic policy and objective of the acquisition process itself to promote technological innovation and to encourage the admission into the field of new businesses and small businesses and the promotion of the interests of minority business enterprises, as well. The point is that S.1264 puts the entire multibillion dollar acquisition process squarely behind technology innovation, with all the implications for collateral assistance to civil sector needs.

It is not too great a stretch to perceive the possibility of employing the new technology and innovation objectives of the Federal Acquisition Act, as a means of promoting research and development in the civil sector, as an adjunct to P.L. 95-224, broadening program implementation alternatives still further.

This objective of the Federal Acquisition Act also directly carries out recommendations of the Commission on Government Procurement, that all executive agencies promote research and development in areas related to their basic mission.

It would appear possible that agencies, in looking at their own direct missions can identify problem areas in the civil sector requiring technological innovation that tie in closely with their own missions. Conversely, the civil sector could identify R&D needs as candidates for matching with related Federal mission R&D needs. The type of R&D inventory work done by NSF might be helpful here.

Such collateral research and development objectives so identified could then be factored into each executive agency overall program.

While this might result in some modest broadening of executive agency missions, and with some cost implication, it would appear, in view of the stated policy objectives of the Federal Acquisition Act of 1977 that such agency matching of missions with civil sector innovation needs would be consistent with the objectives of that Act, and would promote the recommendation of the Commission on Government Procurement in regard to research and development in support of agency missions.

THE TWO STATUTES PROVIDE COMPLEMENTARY AND UNIFYING PROGRAM IMPLEMENTATION POTENTIAL

The point here is that the Federal Acquisition Act, together with the Federal Grant and Cooperative Agreement Act provide a broad basis for program implementation under the control of the Office of Management and Budget.

This means that the total range of authorities for effective program implementation are now brought together at a single point in the Government with control over policy and the ability effectively to promote improvement in both the acquisition and assistance processes.

The opportunity to broaden the mode of program implementation within the acquisition process by the use of contracts under S.1264 is provided by some of the provisions of the Federal Acquisition Act which permit waiver of certain controls, subject to the criteria set out. This provision for waiver of certain requirements in effect provides options within the acquisition process to reflect different roles and responsibilities appropriate to the particular undertaking.

Thus, the two statutes S.1264 and Public Law 95-224, taken together, provide a broad range of administrative instruments and provide for different levels of accountability and control to reflect the roles and relationships between the Federal Government and non-Federal parties that are needed for the particular objectives and strategies involved.

THE SINGLE FOCAL POINT

Another very important factor in the relationship of S.1264 and P.L. 95-224 is the fact that both laws would be under the control and implementational jurisdiction of the Office of Management and Budget. Thus, for the first time the entire process of examining and dealing with effective program implementation alternatives would be brought into focus at a single point within the Government hierarchy, the point at which budgeting control may also be applied.

This new linkage of program implementation controls and budget controls in the Executive Branch has potential of historic proportions.

ACQUISITION EXPERIMENTATION

PROCUREMENT EXPERIMENTATION IN THE FOREST SERVICE

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ABSTRACT

Cooperative efforts by the U.S. Forest Service and the Experimental Technology Incentives Program of the U.S. Department of Commerce, National Bureau of Standards, have resulted in procurement experiments using incentives to private industry for the manufacture of innovative products. The advantages of such procurements to the USFS are in obtaining specialized equipment not readily available in the commercial market, and particularly in passing on some of the costs of related R&D to the private sector. The knowledge gain to the National Bureau of Standards lies in the comparison of effects of various incentives across different product types and procurement environments. Using a case study approach, within a conceptual framework facilitating subsequent generalization of results across agencies, a single experiment is described, from identification of agency need, through commitment of resources, development of prototype specifications, choice of manufacturer, delivery of the prototype, and field test and evaluation, to the attainment of a satisfactory product.

PROCUREMENT POLICY IMPLEMENTATION - CASE STUDY OF THE LEAD AGENCY APPROACH

Floyd Lewis, Stanford Research Institute
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ABSTRACT

A life cycle costing (LCC) can result in dollar and energy savings for the Government when used as a method for the procurement of equipment. The Federal Supply Service (FSS) has been named as the lead agency in sponsoring the use of LCC for this purpose throughout the Government. The current phase of the FSS approach involves the design of an appropriate mechanism for the sponsoring of Government-wide use of LCC. To this end, parties of interest will soon be contracted to obtain their input into the design process.

PROCURING SYSTEMS: EXPERIENCES FROM CIVILIAN AND DEFENSE AGENCIES

Charles W. N. Thompson, Northwestern University

INTRODUCTION

The purpose of this paper is to describe some of the lessons learned (and being learned) in the process of procuring a special kind of system called an "evaluation system." This description draws not only upon the experience with the specific system but also prior experience with the procurement of several military subsystems which, although hardware systems, presented comparable problems. The experience with military systems, and reference to the literature, is used to provide a context within which the special problems of procuring evaluation systems can be observed. This context is presented in the form of a set of dimensional characteristics of systems and a set of strategies particularly appropriate to evaluation systems.

The evaluation system which is the focus of this paper is being procured by the Experimental Technology Incentives Program (ETIP), National Bureau of Standards, to provide a continuing capability to evaluate the results of procurement experiments designed to meet the objectives of both ETIP and the several federal procurement agencies with which ETIP is cooperating. Discussion of these procurement experiments is being presented by other speakers at this session. At the present time, the evaluation system is in the process of development and test of the prototype, the second of three phases.

Although intended primarily to meet the need to procure an evaluation system, the process used to procure the system was, in itself, an "experiment," and is reported more fully elsewhere [14] [15]. This experimental nature of systems procurement is, perhaps not unexpected, and it has been observed that procurement of systems is still undergoing experimentation, at least in a trial and error sense [1:577, 585]. As an experiment itself, the process by which the evaluation system is being acquired and related processes are being more formally examined. It is hoped that these more formal examinations will describe the process and the results obtained, and, more generally, related processes for the design of systems.

The primary focus of the remainder of this paper will be to describe the problems presented in acquiring an evaluation system which is "administratively implementable" [6]. In order to relate the problems (and solutions) here to those more generally presented in the procurement of other systems, a set of dimensions which characterize differences among systems will be presented, following which specific strategies used or proposed in the acquisition of the evaluation system will be described.

CHARACTERISTIC DIMENSIONS OF SYSTEMS

At least since the 1950's the procurement of systems has been recognized as introducing problems in addition to those presented by the procurement of other products and services. These problems occur throughout the procurement process--in defining the system, choosing the contractor, developing (and producing) the system, and putting it into use (implementation). One way to examine these problems is to look at the underlying structure of systems [5:4] [18:239] to identify ways in which they differ. In this section, systems will be described in terms of some selected characteristic dimensions.

Systems tend to have in common three characteristics which set them apart from other procured products and services. They are large, they are complex, and they take a long time to acquire. These characteristics require a large number of people with diverse skills and interests to work together over a long period of time. While this introduces a variety of problems, two will be mentioned here. First, the diversity of skills and interests presents problems of cooperation (or interface) and of communication [10:60] [17] [19]. Technical specialists tend to be concerned with the technical performance of the part they are responsible for and to ignore or give a low priority to other parameters (such as cost, schedule, and interfacing technical parts) [22:41], and they may be insensitive in the demands they make on others [10:60]. Procurement and management people may neither understand nor be "comfortable" with the technical problems [3:62] and may be more concerned with current budgets and schedules, and near-term problems, than with the overall parameters of the system [20:86]. Second, the long time to acquire presents problems with the increased turnover or change in persons who support or oppose the system. Clients, sponsors, and users change jobs, retire, or die; opponents have the time to become informed and organize themselves [16]: requirements may change or competing systems may become available.

While the above comments were directed to characteristics which systems share, there are a number of characteristics or dimensions which may be used to distinguish among systems, particularly with respect to the problems faced in procurement. The discussion which follows will describe a series of selected dimensions; it should be clear, however, that there may be other dimensions of interest. Each dimension will be described, fol-

lowed by a brief discussion of its relation to problems of procurement, particularly noting those relevant to the specific systems which provide the base for this paper.

Hardware ↔ Software

This dimension is the degree to which the system can be described or visualized in terms of specific physical items (Figure 1). Systems which are substantially described as "hardware" tend to be easy to visualize; what is included "within" the system is easy to define; its characteristics (performance, cost, existence) can be identified; and different people can share a common understanding. As the non-hardware component becomes a more significant part of the "system," the system loses its visibility, and it may become more difficult to treat it as a system [1:576] [5:4] [7:1]. Organization charts and process flow diagrams which largely characterize evaluation systems are often difficult to accept as a description of "the system."

Many ↔ Few

This dimension is the degree to which the system will be produced in quantity (Figure 1). Systems which are produced in large quantities differ from small quantity systems [7:23-28] in at least two respects. First, development costs tend to be a significantly smaller proportion of total costs. This may facilitate tradeoffs between development costs and initial and/or operating costs, and the benefits of a large number of systems in operation may make it easier to "justify" the absolute amount of the cost of development. Second, for most, if not all, defense contractors the prospect of production in quantity (and follow-on procurement) is the major incentive. Because the development phase may provide only a breakeven on costs, or even a loss, the contractor will be highly motivated to assure that the system is designed in such a way that it will go into the inventory.

An evaluation system may be procured as a single system, or, at most, it will be limited, initially, to a very few systems. This has the obvious effect of making the development costs a very large proportion of the total cost, and providing for an offset limited to the benefits of only one (or a few) systems in operation. A more serious problem arises, however, in the incentive to the contractor during development; his prospects for recovery, at least directly, are limited largely to his profit on the development. Only if he anticipates the development of additional markets (or is concerned with his reputation as a systems contractor) will he have a strong incentive to designing the system so that it is assured of going into operation.

Incremental ↔ Novel

This dimension is the degree to which the system represents a change from the "system" it replaces (Figure 1). Incremental improvements in present systems tend to be easy to procure (and to put into the inventory); they represent small changes which are easy to understand and to adapt. Most systems procured as systems probably fall into the category of significant improvements on the "present" system, and they present most of the conventional problems of systems procurement [11]. Evaluation systems would usually fall into the next category—systems which nominally replace similar existing "systems." Because the existing "system" may not be recognized as such, or, in many cases, may not "exist," cost/benefit comparisons may be difficult or impossible to make. The final category on this dimension covers novel systems, systems for which is no comparable existing system to replace; these tend to present very specialized problems in procurement, e.g., the system for landing a man on the moon.

This dimension includes a number of roughly paralleling sub-dimensions, a brief discussion of which might serve to distinguish related system characteristics. The degree of change (or novelty) may be with respect to function. In the extreme, the function of the system may be one which no one (seriously) considered possible, or one which hadn't even been thought of; as a consequence, there has been no preexisting need. A closely related change would be where there was a need, but it was assumed that the system couldn't be provided; the change here would be in novelty of payoff or benefit. More commonly, the change (or novelty) may be described in terms of how the system performs its function, or how fast or how well, and changes in how people use it or operate it. Another common type of change (or novelty) is in how the system changes the relationships of people to other systems; for example, the new systems may make obsolete certain categories of personal skills or change an individual's ability to control events. More generally, the change (or novelty) may be in related systems—budgets, policies and procedures, logistics, appropriate technology, etc. Finally, the change (or novelty) may be with respect to non-cooperating individuals or systems—the enemy, competition, or environmental protection groups [16].

Inhouse ↔ Isolated

This dimension is the degree to which the developer of the system is responsive to the direction and control of the user (Figure 1). The highest degree of responsiveness (or, alternatively, the closest relationship) may be expected where the developer is employed directly and specifically by the user; this is a

common form in many industrial organizations and has a long history in the military as the "arsenal concept." Except where the large size of the user organization results in long communication links, and a diffuse control system (i.e., both communication and the reward and punishment structure), the developer who is directed to produce a desired system, and who receives constant review, is likely to be successful in producing a system which will be used. Contracting out introduces all of the problems of procurement, and, most particularly, the problems of choice of contractor, of assigning risk, and of providing review and direction. The problems of assuring that the system that is designed will be used tend to be increased where a third party is the sponsor. Where the developer is the "sponsor," two different situations may appear. If he takes a "marketing approach," i.e., he is designing "to order," the system may be even more likely to be used than in the third party case. However, if the developer takes a "sales approach," i.e., he designs "for stock," his prospects may be much worse. The extreme case on this dimension is the "pure researcher" or "independent inventor" who may even be uninterested in the procurement and use of his product [8:23] [13:43] [22:41].

The specific evaluation system of concern here is under third party sponsorship, although there is a close relationship with potential owners or users of the system, perhaps as strong as many which exist in very large using agencies. It does seem clear, however, that the relationship between the developer and the ultimate user is a critical dimension.

It should be noted that these several dimensions contribute to the complexity of assessing the costs and benefits of a system at various points in its acquisition. And this is true whether the approach is to compare the costs of System A with the benefits of System A, or to compare the ratio of costs to benefits of System A with the ratio of costs to benefits of System B.

SPECIFIC STRATEGIES

The dimensional characteristics of a system may serve to suggest not only the kinds of problems which procurement (and implementation) of the system faces but also strategies which may be used to solve them. In this section a number of conventional strategies, common to many system procurements, will be discussed briefly; following this, specific strategies which have been proposed or employed in the procurement of the present evaluation system will be presented. It should be clear that many, if not all, of these specific strategies have been used, or may be applicable, to procurement of other systems.

Common to most systems is an extensive system definition process, based upon a comparably extensive process of defining the need for the system. The general characteristics previously mentioned--size, complexity, and long time to inventory--require extensive processes for the direction and control to provide an acceptable (and, preferably, the "best" obtainable) combination of performance, time, and cost. Various types of contract forms and incentive systems may be employed, in some cases parallel development will be pursued, and direction and control through review of phases (and milestones), paralleling the research-development-production-use spectrum (or its several variations), is characteristic.

Of particular interest are the following selected strategies which are discussed with respect to their usefulness in the procurement of the specific evaluation system here.

Contractor Selection

Because of the novelty of the proposed evaluation system, it appeared likely that neither the government nor potential contractors would have an in-being capability to design and develop the system. For this reason, among others, the method of procurement involved a lengthy and detailed and candid description of what the government knew, what it was looking for, and how it would select the contractor. The purpose of this full disclosure was to minimize misunderstandings, to provide guidance to potential contractors, and to begin the process (with the selected contractor) of working together cooperatively. This strategy is described more completely elsewhere [14] [15].

Liaison and Review

Because of the novelty of the system, and third party sponsorship, liaison and review were recognized early (as a matter of fact, in the contractor selection process) as critical. Emphasis was placed on on-going, informal exchanges, with the intent that formal reviews and approvals would be after-the-fact confirmations of previously agreed positions. Special attention was given to liaison with the potential user (or "owner") of the system [5:5] [12:7] [14:171-2] [21], but this was complicated by the predominantly software characteristic of the system, its novelty, and the small (but still uncertain) number of systems. Potential users (and others) had difficulty in visualizing (or identifying) the system, including understanding what it would do and its usefulness; the developer had difficulty in identifying specific individuals who would be potential users, and there was more incentive to "develop" than to be con-

cerned with implementation.

Identifying User (or Owner)

Because of novelty, third party sponsorship, the software nature, and the small quantity, the identifying of a specific user who could work with the developer to assure that the system as designed would be acceptable took more time than anticipated. It was recognized, however, as a critical priority. Where the "present system" to be replaced is not necessarily a specific entity, with some organizational element (or individual) clearly responsible not only for the present system but also the new system, the identification of the specific individuals who will be responsible for implementation and use may be very difficult. It requires specific individuals to provide guidance on how a "novel" system will fit into other existing systems, who can plan the training, budgeting, personnel, and space requirements, and can coordinate the process of implementation. And even under the best of circumstances it requires the "best people" and, usually, with strong, senior support [2] [9:121] [12:7].

Key Man (or Advocate)

Because of the small quantity, and perhaps because of the software nature and the novelty, it is critical that the system have an advocate or "salesman" who can not only "push" the system into existence but also find the "pull" represented by the ultimate user (or owner) [4:586]. This presents a potentially difficult problem in a novel and small quantity system because development engineers with special technical competence may find it difficult to give equal attention to meeting user needs; similarly, user oriented advocates may be less interested (and less competent) in technical development [8:23] [13:43] [22:41]. In large systems procurements this problem is met by either functional specialization or employment of systems people with skills in both areas, or a combination. In small systems procurements, the options may be more restricted.

Prototype System Model

The procurement contemplated three stages, each centered on the evaluation system as it developed, as follows: pilot evaluation system (essentially the initial design of a "single thread" system); prototype evaluation system (a contractor operated version of the system as proposed); and on-line evaluation system (a user operated version of the system, with some contractor assistance). The prototype evaluation system was also proposed to be used not only to test the system design but also as an identifiable, visible model which the user could "see" in operation, which he could use as the basis for suggesting refinements and modifications, and which he could use as a basis for planning the installation and operation of the on-line evaluation system.

Particularly because of the non-hardware characteristic and the novelty, it was considered important that there be a "visible" system for the user to "see." This capability is one that is provided, even for hardware systems, in the form of simulations, mockups, demonstrations, models, and various graphical representations. For an evaluation system, it seems clear that the need may be much greater.

SUMMARY

Experience with the acquisition of an evaluation system has been presented in terms of a set of dimensional characteristics which distinguish different systems and specific strategies used or proposed in the acquisition of the evaluation system.

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FIGURE 1

SELECTED DIMENSIONAL CHARACTERISTICS OF SYSTEMS

Hardware —— Software Dimension

The degree to which the system can be described...in terms of...physical items

Completely ←——→ Not at all

Hardware Subsystems (e.g., aircraft)	Weapon Systems	Logistics Systems	Evaluation Systems *	Management Systems

Many —— Few Dimension

The degree to which the system will be produced in quantity

Very much so ←——→ Not at all

Very Large Quantities	Large Quantities	Few or One	None
Small, Expendable Weapons Systems	Major Weapons Systems	Construction Projects	Demonstration Projects
		Evaluation Systems *	

Incremental —— Novel Dimension

The degree to which the system represents a change from the "system" it replaces

Not at all ←——→ Completely

Incremental Improvement (or Alternative) To Present System	Significant Improvement On Present System	Replaces Nominally Similar "System"	No Comparable Present System
Product Improvements	Major Weapons Systems	Evaluation Systems *	Apollo Project Manhattan Project

Inhouse —— Isolated Dimension

The degree · which the developer of the system is responsive to...the user

Completely ←——→ Not at all

Subordinate Organization	Contracted Out	Developer Funded "To Order"	Third party Sponsor	Developer Funded "To Stock"	Pure Research Or "Inventor"
Industrial R&D "Arsenal Concept"	Major Systems Acquisition		Evaluation Systems *		

*Note relative position of Evaluation Systems

PROCUREMENT EXPERIMENTATION IN THE VETERAN'S ADMINISTRATION

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ABSTRACT

The procurement area of the Experimental Technology Incentives Program (ETIP) at the National Bureau of Standards has as one focus the impact of procurement incentives on innovation in developmental products. The medical products field is thought to offer considerable potential for procurement experimentation. ETIP is pursuing a mixed strategy for identification of product areas as targets of procurement changes. The strategy involves both searching within a health care delivery agency for user needs that might be met through procurement, and searching in industry for new trends in product development that might be pulled through procurement incentives. To date, the Veteran's Administration, the largest single hospital system in the United States, has been ETIP's partner agency in medical products procurement. This paper will outline ETIP/VA experience in developing and conducting a program of procurement experimentation.

PROCUREMENT EXPERIMENTATION IN THE VETERANS' ADMINISTRATION

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ABSTRACT

The Procurement Area of the Experimental Technology Incentives Program (ETIP) at the National Bureau of Standards has as one focus the impact of procurement incentives on innovation in developmental products. The medical products field is thought to offer considerable potential for procurement experimentation. ETIP is pursuing a mixed strategy for identification of product areas as targets of procurement changes. The strategy involves both searching within a health care delivery agency for user needs that might be met through procurement, and searching in industry for new trends in product development that might be pulled through procurement incentives. To date, the Veterans' Administration, the largest single hospital system in the United States, has been ETIP's partner agency in medical products procurement. This paper will outline ETIP/VA experience in developing and conducting a program of procurement experimentation.

BACKGROUND

ETIP

The Experimental Technology Incentives Program (ETIP) within the National Bureau of Standards is tasked with developing knowledge on the impact of government policies on private sector technological innovation. One area of continued emphasis has been to examine Federal and, to a limited extent, state and local acquisition policies as barriers or incentives to product innovation in industry. The principal means of examining acquisition policy impacts has been the administrative experiment, a cooperative arrangement in which the product procurement needs of an agency are met while simultaneously allowing ETIP to develop data regarding industry response to such procurements (Thompson, 1974; Thompson and Rath, 1974). To facilitate acquisition experimentation, partnerships have been formed with agencies who have acquisition responsibility as a principal component of their missions.

VA

A partnership between the Veterans' Administration and ETIP was formalized during the initial years of the Program to develop experience in the procurement-innovation link in health care delivery, the largest service industry in the U.S. economy. The VA was considered the appropriate agency for this particular focus of the ETIP Procurement Area because the "VA supply service supports the most extensive medical program in the Federal Government...(and) the procurement process of the VA can and should be a major influence in contributing to improvements in the nation's health care delivery system" (ETIP Project Plan #8, pp 1-2).

Acquisition experimentation within the VA offers a good illustration of the administrative experimentation arrangement. The VA Supply Service through its marketing center is able to apply procurement tools that have not enjoyed consistent application in the past in purchasing innovative equipment and supplies in keeping with its mission. At the same time, ETIP is able to extend its procurement-innovation knowledge base in areas untouched by its experimentation with other agencies. To facilitate development and execution of acquisition experiments, an office has been established within the Testing and Evaluation Division at the VA Marketing Center at Hines, Illinois.

FRAMEWORK FOR PROCUREMENT POLICY DEVELOPMENT

An ongoing ETIP effort simultaneous with the conduct of specific procurement experiments is development of a framework to categorize and aggregate the procurement innovation bits of knowledge resulting from those efforts. One of the earliest formulations of this framework recognized aspects of the VA which would contribute to ETIP's understanding of the impact of government acquisition policy on innovation. One feature of the VA procurement function is that it acts as an "owner/user purchase"; in other words, the VA both purchases and uses the supplies it acquires. This is in contrast to the Federal Supply Service, another partner agency with ETIP, which acts as a broker between users in other government agencies and industry, on the products it buys.

As work in the procurement area has progressed, attempts have been made to incorporate some of the literature on innovation in industry. In particular, efforts have been made to incorporate the notion of the "product life cycle" or "product growth curve" as discussed by Abernathy and Utterbach, Tilton and others. Briefly, this literature recognizes both product and production process innovations and postulates maximum policy impact on product changes when design alternatives are under evaluation. Once design parameters become more secure, the cost of making changes becomes more expensive and the innovation focus shifts to process changes. Finally,

as the product matures, emphasis is no longer primarily on product or process innovation, but on cost reduction (Abernathy and Utterback, 1975).

The VA seems to offer an opportunity to explore products in the developmental stage. Again, this is in sharp contrast to the FSS example where much ETIP work has been done with mature, energy intensive products.

STRATEGY FOR SELECTING EXPERIMENTS

The framework elements will ultimately help guide the selection of experiments within the VA system. However, experiments were initiated prior to development of the framework and a variety of sources continue to contribute experiment ideas.

Product Champions

Several experiments were initiated early-on in the ETIP/VA relationship as "getting-our-hands-dirty" experiences. Most of these ideas were first identified in a consultant's report exploring the VA as a possible site for acquisition experimentation. Three products--surgical gloves, the portable oxygen producer and the hypodermic device destructor--were selected for the first cycle ETIP/VA experiments.

Surgical Gloves

The surgical gloves experience was an attempt to purchase a "preferance item," one for which different users have different concepts of desirable qualities, using performance specifications such as tensile strength, or stiffness of material. There was no particular individual with the VA system who was actively involved, or "championing" this product. The approach taken to development of a specification was an industry symposium followed by a task force and industry effort to produce a specification. The resulting specification was not useful for purposes of procurement and the experiment was dropped.

Two bits of knowledge were gained from this experience for future ETIP/VA ventures. The first is that evaluation of the impact of a procurement of a preference item would have been a complex task at best. Since measures of satisfaction would necessarily reflect these preferences, a conclusion as to whether or not a better glove had been purchased would be extremely difficult to draw. Second, the surgical gloves experience seemed to indicate that it was difficult to get an experiment going and sustain its momentum without an identifiable individual or group interested in obtaining the resulting product.

The concept of a product champion was used in two subsequent acquisition experiments, the portable oxygen producer and the hypodermic device destructor. Both products were actively sought by the Director of the Department of Medicine and Surgery in the VA Central Office as significant contributions to the delivery of patient care.

Portable Oxygen Producer

The portable oxygen producer, was an attempt to use the procurement process to pull a substantial change in the state-of-the-art. A performance specification which described a device free from an external power source and light enough for patients with pulmonary disabilities to carry, in addition to other characteristics related to noise, safety, and internal oxygen storage was developed. The experiment was innovative in several ways: notably, performance specifications were rarely used in VA acquisitions, and the particular product sought was unavailable at the time of the VA procurement. A two-step prototype of procurement was used as it was recognized in the VA as providing a means of promoting competition for new or improved technologies under the provisions of the VA procurement regulations. Technical proposals were submitted by two firms; both were unresponsive. Lessons learned from the effort were several. For purposes of initiation of ETIP/VA experiments:

- The existence of a product champion is very helpful.
- Future experimental efforts should involve careful pre-IFB assessment of market trends and market potential for the product in order to ensure responsive bids.
- Careful assessment of customer needs and priorities within them should precede experimental procurements.
- The degree of advancement in the state-of-the-art should be explored and the following alternative acquisition techniques examined:
  - -- For a series of small state-of-the-art advances, prototype procurement with a prioritized set of performance specifications may be appropriate.
  - -- For large advances in the state-of-the-art a cost-reimbursable R&D approach may provide a greater incentive for product [illegible] than a two-step prototype.

-- For no real change in the state-of-the-art, performance specifications alone may suffice. (McEachron and Woodward, 1976)

Hypodermic Device Destructor

The second product championed by the Department of Medicine and Surgery was the hypodermic device destructor, a contemporary of the portable oxygen producer in the ETIP/VA procurement experimentation. The project was in many ways similar to that of the portable oxygen producer: the two-step prototype procurement technique with performance specifications was used. However, unlike its contemporary, the hypodermic device destructor procurement sought a moderate advance in the state-of-the-art. In fact, the VA was the procurement as a means of spurring its current supplier to make better use of existing hypodermic device technology. Again, the procurement was not completely successful in that none of the bidders were immediately responsive to the procurement; however, the VA expects to obtain the desired device through follow-on with several bidders.

Contrary to initial expectations, the bidders offering device destructors to the VA were not current suppliers but rather small compaction-equipment manufacturers who were not factors in the medical device market. The VA has made efforts to bring the most promising bidder up to specifications. In the meantime, another small concern has developed and demonstrated a device destructor that very nearly meets the initial specification. Plans are to do a detailed case study of the circumstances under which this device was developed and offered to the VA market.

There is some indication that regulation was a prime motivator in development of the hypodermic device destructors offered to the VA in response to this acquisition experiment (McEachron and Chandler, 1976). While the small firm offering the most promising bid seemed to feel that Federal regulations were moving in the direction of more stringent syringe and needle destruction specifications, the larger firms already in the industry did not regard this as the trend. Furthermore, the larger firms were moving in the direction of cheap, simple destruction devices without decontamination features sought by the VA.

Many of the lessons suggested by the portable oxygen producer were again suggested by the hypodermic device destructor:

° The existence of a product champion within the VA is extremely useful in initiating and completing acquisition experiments.

° Careful market trend and market potential assessments should precede experiments to maximize the likelihood that the desired product is obtained.

Agency Problems

Another approach which is frequently used by the ETIP/VA in identifying candidate products for acquisition experimentation is to make use of existing products. Those approached offer the advantage of identifying a champion for the product as discussed above. Two such systems are the QIR (Quality Improvement Report) and the Hazard Reporting System. Both offer opportunities for the ETIP office within the VA to pinpoint products with which users have had problems and to screen them for products that have promise for technological improvement and commercialization in keeping with the ETIP mission. The VA has also been used as a site for testing of a system developed at the FSS to match user product improvement ideas with industry ideas. Four candidate products have come from this source.

Industry Problems

A special effort was initiated by ETIP/VA to determine the workability of investigating industry improvement ideas first, then matching them with agencies with procurement responsibility. A Medical Products Search was conducted by a contractor, which identified and ranked ten product ideas. ETIP/VA is now in the process of finding champions within the VA for those of the products used within the VA system. The process has not yet been fully evaluated.

SUMMARY

The program of experimentation with medical products has been somewhat slow in yielding a proliferation of new products. A number of strategies are being pursued to identify candidates for experimentation. These ideas are then matched with experience gained from three early "getting-our-hands-dirty" procurements described in this paper.

The VA experience has offered some opportunity to expand elements of the ETIP Framework for Procurement Policy Development and is expected to make numerous additions in the future.

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COMPETITION

DUAL AWARDS AND COMPETITION - YOU CAN HAVE BOTH

CAPTAIN DARRELL R. HOPPE, A-10 SYSTEM PROGRAM OFFICE

BACKGROUND

After completion of a competitive prototype phase and a formal source selection with negotiation, the A-10 System Program Office (SPO), Wright-Patterson AFB OH awarded contracts to Fairchild Industries, Inc. and General Electric Company for the A-10 Close Air Support Airframe and GAU-8/A 30mm Gun System respectively. General Electric's contract specified Full Scale Development (FSD) and initial follow-on production of the Gun System and 30mm ammunition. At that time (1973), General Electric was teamed with Aerojet Ordnance and Manufacturing Company (Aerojet being the subcontractor) for ammunition FSD and production. In 1974, as a result of DSARC II, GE was tasked to develop a second ammunition source and thus provide the framework for a mobilization base and competitive sources of supply. The premise used for the dual sourcing was that the Government through competition: (1) obtains fiscal year production quantities of ammunition; (2) maintains defense industrial capability and capacity; and (3) procures ammunition at a lower total cost. The second source developed was Honeywell Inc. and through the joint A-10 SPO, GE, Aerojet and Honeywell efforts, the types of ammunition presented in Table 1 have evolved.

In 1976, A-10 SPO management decided to procure FY77 requirements directly from the two ammunition subcontractors. Both subcontractors were progressing well and each had been awarded at least one production quantity through GE. A Request for Proposal (RFP) was issued directly to Aerojet and Honeywell pursuant to 10 U.S.C. 2304(a)(16), "Purchases in the Interest of National Defense or Industrial Mobilization". The RFP contained a Minimum Sustaining Rate (MSR) of production specified for each contractor at 20% of the total procurement. In other words, each contractor was to receive a minimum of 20% of the total rounds procured for FY77. Above this minimum, the offerors were asked to propose at bid points of 16% intervals (i.e. 20/36/52/68/84/100%) of the total buy. The evaluation criteria in the RFP contained two factors - cost to the Government and support and planning for mobilization requirements. The RFP also included the requirement for Cost and Pricing Data and submission of a Certificate of Current Cost or Pricing Data after determination of the total award split. Full field analyses (DCAS Price Analyst/DCAA/Technical) were accomplished and used in in-depth discussions with each contractor. After conclusion of discussions, a Best and Final Offer (BAFO) was received from each offeror and the award process continued using the evaluation criteria in the RFP. The end result was that both offerors were awarded quantities above the MSR and the presence of competition weighed heavily in the determination of acceptable prices to the Government. In summary, we had satisfied all of the objectives of the GAU-8/A 30mm ammunition program which were as follows:

1. Establish and Maintain a Defense Mobilization Base - This was accomplished by including an MSR in the RFP pricing structure and mobilization support factors in the evaluation criteria.

2. Maintain Two Sources - Awards above the MSR insured two viable sources would be able to compete on an equal basis for future awards.

3. Introduce and Maintain Competition - The element of price competition was present throughout the award process.

A post-award review of the FY77 procurement process revealed areas in need of improvement for the future. These areas were identified as follows:

1. Minimize Proposal Points - The six proposal points were too numerous and made proposal preparation and evaluation unduly tedious and complex.

2. Specify Interpolation Method Between Points - The interpolation method for ammunition prices for award quantities between two points was unspecified in the RFP. The only requirement was that each contractor have an interpolation method. This open item in the award process could have impacted the prices paid for ammunition.

3. Incentivize Every Potential Award Point - It was recognized that even though price competition was present there was little competitive pressure on the MSR and it was potentially to an offeror's advantage to make the MSR as unattractive as possible in comparison to the other award points.

4. Capitalize On the Competitive Environment - Price competition was present in FY77 but we felt the competitive pressure was dampened to some degree by the RFP structure in two basic ways. First, proposal points were treated essentially as independent entities and the offeror's decision as to price at one point (the minimum quantity for example) did not necessarily influence his price decision at another. Secondly, the RFP as previously mentioned contained subjective evaluation

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criteria for award and the offerors knew that price was not the only determining factor. We recognized that future buys would have to make pricing decisions interrelated and that subjective criteria would have to be eliminated to gain true price competition.

FISCAL YEAR (FY) 1978 DUAL COMPETITIVE AWARD METHODOLOGY (DCAM)

As a result of the FY77 lessons learned, the FY78 RFP was structured around the basic premise that awards to both offerors would be made solely on the basis of price competition. As a result no Cost or Pricing Data was required and Field evaluation of proposals was not conducted. The key, of course, to this change was the establishment of a mechanism that insured competitive prices at every possible award point. The RFP established three proposal points to be used in the award evaluation and required that each of these points be on a single continuous logarithmic total price curve. Each offeror was required to supply the equation and plot for the curve as part of the proposal. This equation was then used to establish the contract price for any quantity of ammunition purchased at or between the points. In essence then, we had improved on our shortcomings in FY77. We had decreased the number of proposal points and specified the interpolation method to be used between points. Proposal points were no longer being treated independent of one another and price decisions made at one point by an offeror influenced all other points. We now had to insure that increased competitive pressure was applied to each point. The points established for evaluation were 35%, 50% and 65% of the total buy. The important factor here is the minimum quantity to be awarded to each offeror. The minimum quantity was increased from 20% to 35% of the total so as to include and satisfy all of the subjective criteria formerly contained in the FY77 RFP (mobilization planning, future competitive posture, surge capability, etc.). Once these criteria were satisfied, price became the only evaluation factor and the Dual Competitive Award Methodology (DCAM) evolved.

In essence, DCAM involves: (1) averaging the three proposal points after adjusting them for competitive advantage (Government Facilities, Transportation Factors, Government Furnished Material, etc.); (2) determining the percentage difference between the offeror's average adjusted prices; and (3) applying this percentage difference to an award decision matrix to determine the percent award for each offeror. Step (1) then uses the following Dual Competitive Award Formula (DCAF).

$$AACB = \frac{ACB_{35} + ACB_{50} + ACB_{65}}{3}$$

where
AACB is the Average Adjusted Contractor Bid
ACB_n is the Adjusted Contractor Bid at 35%/50%/65% respectively.

After an AACB is calculated for each offeror, the Δ% between the two is calculated (Step 2)) as follows:

$$\Delta\% = \frac{\text{Highest AACB} - \text{Lowest AACB}}{\text{Lowest AACB}} \times 100$$

This result is then applied (Step 3)) to the award decision matrix given in Table 2. Reading the table from left to right provides the award percent for each offeror given delta percents from 0 to 12%. This matrix was developed by examing past ammunition data and projecting prices. In essence, Cost Improvement Curves in a reasonable anticipated slope range of 85% to 95% were "gamed" on the computer to examine the range of reasonable average percentage differences between two competing firms. If this reasonable difference exceeded 12%, the RFP anticipated the DCAM approach would be abandoned and in-depth negotiations would be conducted with each contractor. The matrix essentially rewards the offeror who is the most competitive within the reasonable range or penalizes the offeror who is less competitive.

The total DCAM concept improves every area of concern identified as a result of the FY77 procurement.

1. Proposal Points Were Minimized - Six were included in FY77. Only four points were used in FY78. Three for the evaluation (35/50/65%) and a fourth (75%) for potential increases in quantities.

2. Interpolation Method Was Specified - The logarithmic equation was used for all prices along the line.

3. Every Award Point Was Incentivized - The DCAF treats all points equally in the evaluation and uses the interdependence of prices at all three points.

4. The Competitive Environment Was Used to Better Advantage - Minimum award quantities can no longer be unnecessarily "loaded" without influencing the outcome of the evaluation. "Loading" penalizes an offeror's chances of receiving the larger share of the award dollars. Adjusted price is the only thing considered in the evaluation and the degree of competitiveness between the prices offered dictates the award quantity for each offeror.

RESULTS

The FY78 DCAM results were truly dramatic. By awarding on the basis of price competition,

procurement cycle times were decreased drastically. With the elimination of DCAA, DCAS and Aeronautical Systems Division Pricing involvement as well as factfinding and negotiation, the procurement cycle was reduced from 322 calendar days to 158 calendar days - 51% less time! This reduction in time allows us to better plan for our annual procurements and concentrate on the requirements to be met instead of the mechanics of award. The system is continually being evaluated and we hope to eventually reach a cycle time of less than 128 calendar days for the award of two complete contracts totaling in excess of $100 million! We are proud of this accomplishment, but the real proof of the system is in the prices we pay for our ammunition as compared to what we might have paid using other methods. Estimates for FY78 savings alone point to a potential ammunition reduction of $17 million below projected dollar amounts. This is a significant reduction considering the FY78 buy was less than $100 million. The savings were so great, in fact, we were able to buy 115% of our original requirement for less than the dollar projection for the 100% quantity. This is an indication that we can indeed have dual contract awards - with a guaranteed minimum mobilization quantity - and still have price competition.

POTENTIAL AREAS OF APPLICATION

The DCAM procedure was developed specifically for the GAU-8/A 30mm ammunition program and most likely cannot be used on other programs precisely as presented here. For example, minimum quantities would change, the bid points could be different, the award matrix and parameters require individual analysis, etc. depending on the situation. However, the principles and concepts involved may prove useful in other procurement situations especially where dual sourcing and awards are involved. Within Government procurement, the leader-follower concept may be able to use some or all of the DCAM. Also, prime contractors who dual source at subcontract level may see some advantages and benefits to DCAM. Of course, other mobilization base programs within the Government would be prime candidates for DCAM applications. Future applications of DCAM or other improved procurement techniques are only limited by the imagination of those who develop them and the willingness of others to accept and implement them. The A-10 SPO, ASD and AFSC have the capacity and management capability to do both.

TABLE 1

GAU-8/A 30MM AMMUNITION

TYPE	PRIMARY USE
Target Practice (TP)	Training (Live Fire)
High Explosive Incendiary (HEI)	Fire Start
Armor Piercing Incendiary (API)	Tank Killer
Dummy	Gun Cycling, Training

TABLE 2

AWARD DECISION MATRIX

Δ%	AWARD % LOWEST AACB	AWARD % HIGHEST AACB
0 thru .5	50%	50%
.5+ thru 2.5	55	45
2.5+ thru 3.5	56	44
3.5+ thru 4.5	57	43
4.5+ thru 5.5	58	42
5.5+ thru 6.5	59	41
6.5+ thru 7.5	60	40
7.5+ thru 8.5	61	39
8.5+ thru 9.5	62	38
9.5+ thru 10.5	63	37
10.5+ thru 11.5	64	36
11.5+ thru 12	65	35
GREATER THAN 12	TO BE NEGOTIATED	

DUAL SOURCING IN MAJOR WEAPON SYSTEMS ACQUISITION

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I

INTRODUCTION

Dual sourcing, or second sourcing, in the acquisition of major weapon systems is not a new concept. In an attempt to introduce and maintain competition in the acquisition process, various methods have been proposed and utilized. Over the years, the methods and techniques may change but the same problems continue to exist. One of the methods which has been explored for introducing competition in the production phase has been second sourcing. The acquisition literature lacks a uniform definition of second sourcing. For the purposes of this article, however, second sourcing is attempted where the specifications have been developed and a sole source producer (usually the developer and original source) is currently producing the item. This would exclude acquisition actions involving:

- parallel developments under research and development programs where two contractors are usually concurrently funded for prototype hardware development leading to a "fly-off"
- obtaining an item from a new source subsequent to a default termination
- component breakout, involving the decision as to whether components should be purchased by the Government directly and furnished to an end item contractor as Government Furnished Material (commonly referred to as GFE) or purchased by the contractor (CFE)
- the splitting of award under invitation for bids procedures usually resulting from Small Business or Labor Surplus Area set-asides as well as evaluations of bids under IFB procedures leading to multiple awards

Dual sourcing has not been accomplished without serious difficulties. One researcher identified the following problems which surfaced during testimony before congressional committees over a period of several years:

1. In some cases, there has been no concerted effort to obtain the needed technical data package. The project manager involved fears that money will be wasted

2. The cost of obtaining a second source is a critical decision. In many cases, adequate planning, information on volume, and cost data are not available to make that decision

3. Much of the technical data prepared during initial development is of little worth. Contractor design changes depreciate the value

4. Project offices experience difficulty in obtaining and maintaining control over technical data packages. Cases have been cited in which the Government was not certain of what data it had and whether the data was adequate for use by a second source

5. Much of the data is not delivered in time to be of use by the project office and is not of sufficient quality for use by a second source

6. There is a question of data ownership. Often the data needed are owned by the contractor and he is reluctant or refuses to sell

7. There is a problem of transferring technical data from one contractor for use by a second contractor because company processes differ (1:142-143)

II

REASONS FOR DUAL SOURCING

Dual sourcing is generally initiated as a result of two broad policies or concepts: competition and mobilization production. In the case of the first concept, a second source is sought in order to introduce competition on both a price and technical basis into the acquisition process. The intent here is to force the original source, as well as the second source, to become as efficient and as low a cost producer as possible. Naturally the element of competition always puts a different complexion on the procurement and it generates those market place factors so visibly lacking in the sole-source environment. In this situation, the developer (the original source) will participate in the competition with the award made to that responsible and responsive firm with the lowest price.

The second major category of second sourcing is that involved for purposes of meeting mobilization production capacity requirements. The Defense Acquisition Regulations (DAR) provide general authority to develop and implement plans and programs to provide an industrial mobilization base which can meet production requirements for essential military supplies and services and specifically accommodates the division of production requirements between two or more contractors to provide for such a base. In such a case, the Secretary must determine that the interest of industrial mobilization, in case of national emergency, would be subserved by negotiation with a particular supplier.

It is important to note that the Government has no obligation to make the second source fully competitive, a mistaken idea that many contractors vehemently maintain. This is not to say that competition isn't an objective because one of the prime benefits from second sourcing is major price reductions. The second source can be made fully competitive only if the Government can substantiate large tooling investments above the minimum sustaining rate, e.g., large enough quantities over a sufficient period of time.

Mobilization second sourcing is accomplished by a competition among a group of contractors well established as producers of the items to be procured. This competition specifically excludes the original source (current producer) and the winner of the competition is usually given a small initial learning quantity to insure the second source can produce a quality product. This contract may include an option to procure follow-on quantities when the learning quantity has been successfully tested. The remainder of the current fiscal year buy would then be awarded to the original source.

In subsequent annual procurements, the two sources are solicited for competing proposals on a step-ladder quantity basis. The Request for Proposals (RFP) will generally state that the Navy intends to award on the most economical basis for the Government. This will usually result in a larger quantity to the original producer and a smaller quanity, consistent with minimum sustaining rate requirements, to the second source.

In evaluating the quantities to be awarded such factors as existing tooling and the cost of adding tooling and test equipment for higher levels of production are important.

It is obvious that in the production of a complex system, the second source will not be immediately competitive with the original source. During the first few annual procurements, therefore, it might be necessary to determine the reasonableness of prices through cost analysis - as opposed to price analysis - and to require submission of cost or pricing data. If one or both contractors cannot be awarded a definitive firm fixed-price contract on the basis of price analysis, the usual procedure would be to issue a letter contract, to protect the delivery schedule, and to immediately begin the definitization process. Letter contract conversion is planned to be accomplished within six months after award. Performing cost analysis provides the Government an opportunity to inspect the Contractor's estimating and costing systems which might not otherwise have occurred under a production environment if a definitive firm fixed-price contract had been awarded. Such analyses provides a basis for such decisions as learning curve applications and perhaps future "buy out" or "winner take all" competition.

III

REQUIREMENTS FOR DUAL SOURCING

Some basic requirements exist which must be satisfactorily met before embarking on any second sourcing efforts.

The first, and perhaps most important, requirement is an extremely good technical data package. Even with the most tried and tested specifications, new sources will have some technical difficulties as a result of different production engineering approaches. It may very well happen that second sources who quote tight prices in competition will, sub-

sequent to award, go over the specifications with a sharp, bright light scrubbing the package intensively in order to support deficiency claims. This is not to say that every second source contractor will submit claims against the Government, but the opportunity clearly exists. Whether or not the Government owns the data package is yet another consideration. If the developer has proprietary data in the technical data package, the cost of getting unlimited rights or reprocurement rights must be added to second sourcing costs. In most instances the developer is usually the current producer on a sole source basis although he may have won his sole source status through earlier competition. The item should be in production in order to ensure the technical data package is adequate and most production problems have been identified and resolved.

A second requirement is that large enough quantities to make second sourcing worthwhile for both Government and industry must exist. Many hardware items require large initial production start-up costs which contractors must be able to amortize over future annual buys. The potential for large future quantities might include a multi-year procurement package. Not only must there be sufficiently large quantities but these quantities must exist over a period of several years.

A third requirement is that in the case of sophisticated, complex systems, it is mandatory that the Government have qualified technical personnel to assist the second source, particularly during the learning quantity or pilot production phase. These qualified personnel have to know "how to assist" because in some instances there is a tendency to over-engineer the problem or drag it out extensively. The original source (competitor) usually won't help with problem areas he may have already learned to overcome. It is important that "take apart and study" models of production hardware be available to the second source in order to facilitate his complete understanding of the finished product.

The fourth major requirement is that interested sources exist to compete in second sourcing efforts. It may very well occur that problem areas experienced by the current producer are of sufficient magnitude to discourage any interest in competing. Some contractors have adequate knowhow to compete but need to be talked into redirecting their resources to this new business. In some cases, it means demonstrating to a potential contractor that the risks of second source investments can potentially result in rather profitable business. Second sourcing won't work if serious sources cannot be established and the original source is keenly aware of his competitors.

Fifth, sufficient administrative lead-time must exist to develop the second source without jeopardizing delivery schedule requirements. Included in this lead-time are such efforts as (1) first article qualification, (2) learning quantity award, (3) pre-award surveys, (4) competitive range evaluations, (5) meaningful discussions, both written and oral, and (6) best and final offers (when appropriate).

In summary, several requirements must be met in order to initiate second sourcing efforts. It is important to note also that only under an exception 16 (mobilization base) can the original source be excluded from second source competition.

IV

BENEFITS OF SECOND SOURCING

Several benefits result from successful second sourcing, not the least of which is price reductions. In sole source procurement, many of the factors found in the competitive market place are missing and must either be simulated or safeguards against commercial abuses established. Second sourcing introduces the competitive environment, even though not always completely, and forces contractors to sharpen their estimating pencils and scrutinize cost efficiencies as a necessity rather than a luxury. Cost consciousness frequently spreads to other programs in the contractor's plant and is even forced down to subcontractor levels in order to remain competitive. Even beyond this, other major firms in a particular industry, e.g., missile manufacturers, observe how a particular contractor is establishing operating efficiencies which may stimulate similar efforts in their plants as well as how they perceive their relative strength to compete in existing future missile programs.

An improved technical data package and improved equipment performance frequently results from second sourcing. A fresh new examination of the hardware by a second group of competent engineers often results in technical improvements and better problem solving techniques. Because the program is now competitive (or becoming competitive), the original source may shift his best talent to the second sourced program in order to become more efficient. Naturally the second source will want his most capable people on the project in order to become competitive as rapidly as possible.

Another benefit of second sourcing is the existence of two sources for the same item at the same time which acts as a measure of insurance against delivery delays due to such occurences as strikes, natural disasters, technical problems, and similar instances. Further, as one producer discovers a problem with the technical data package or a method of improving production processes, this can be incorporated (by change order) into the other producer's item.

Yet another benefit of second sourcing is the orderly development and maintenance of an industrial mobilization base. Mobilization asset requirements can be met while achieving competition at the same time. Mobilization requirements are used as a basis for second sourcing in the first place, but the two are self-reinforcing.

Corollary to the mobilization benefit is the maintenance of a resource base for new initiatives in down-stream applications. This may involve R&D studies for Government developed applications or contractor developed prototype hardware for concept testing and evaluation. Additionally, several second sourcing efforts have involved small businesses such as fuze antennas, safety and arming devices, and electronic assemblies. In such cases, small business objectives can be achieved while broadening the business base at the same time.

V

EXAMPLES

NAVAIR procurements fall into the following major categories: airframes and engines, missiles, avionics and sonobuoys. In terms of weapon systems, missiles peculiarly lend themselves to second sourcing because it can be anticipated that a large enough quantity will be procured thus making heavy contractor and Government investments in initial start-up costs profitable. At NAVAIR, our component breakout policies permit us to second source both expensive and relatively inexpensive missile components. Our major primes are the guidance and control section contractors. Other missile component primes include the warhead, target detecting device, rocket motor, and wing and fin producers. Large quantities and mobilization requirements also make sonobuoys extremely attractive for second sourcing. Almost 65% of NAVAIR's sonobuoys are currently second sourced.

As an example, Contractor A developed a particular navigation set and was awarded a FY 75 contract at a unit price of approximately $25,000. The FY 76 procurement was split between Contractor A (unit price of $27,150) and the winner of a competition (Contractor B) at a dramatically lower unit price ($13,785). One could speculate that competitive forces sharply reduced the unit prices both to Contractor B in FY 76 and in FY 77 when Contractor B received the entire annual buy at a unit price of $12,875.

This navigation set is an example, however, where problems in second sourcing can occur. Contractor B had technical difficulties in first article approval which were attributed by the contractor to the data package. It appears that the drawing package was not in complete agreement with the model. In the FY 78 requirement, steps were taken to highlight known problems. For example, a provision was incorporated in the RFP notifying bidders that wiring lists and test specifications in the technical data package are inadequate for their intended use and that offerors should take this into consideration in preparing their proposals because no contract adjustment will be made for the deficiencies noted. In another special notice regarding drawings, offerors were advised that there is reason to believe that defects may exist in certain drawings, that other drawings not specified may also have defects, that offerors are advised to carefully examine the data package, that any such defects are considered "patent defects" as defined in the patent and latent defects clause, and finally that offerors should consider these facts in preparing their proposals (both cost and schedule impacts) and any increased effort associated with correcting defective drawings. These notices serve to warn the bidders that known defects exist and should be accommodated in proposal packages.

In another example, although a particular missile rocket motor is not currently second sourced, an analysis of the feasibility and desirability of second sourcing this item in FY 75 was inititated. When the original source discovered the existence of second sourcing actions, it commenced some significant cost reduction measures. As a result, the FY 77 unit price was less than one-half the unit price realized in FY 73/74. Some of this is due to learning and other operating efficiencies, but a significant percentage of the reduction can be attributed to the "threat" of a second source.

VI

LESSONS LEARNED

Several lessons have been learned from past and on-going second sourcing efforts. The first cardinal rule is to have as adequate a technical data package as possible. Second sourcing efforts may be advisable in all other respects but until the data package can be pronounced "completely adequate", serious consideration should be given to the technical problem which could develop.

Secondly, there must be a very thorough, competent and impartial evaluation of the second source proposals. It is extremely important to identify the overly optimistic cost and schedule promises of competitors.

Next, it is important to select the appropriate type of contract for the second sourcing effort. The specific contract type depends upon the peculiar facts of each individual procurement, however, a cost-type contract is usually appropriate for the "learning quantity" awarded to the second source. Progressing from a cost-type learning award to a fully competitive firm fixed-price contract depends upon a number of factors including the contractor's ability to come rapidly down the learning curve.

Fourth, it must be recognized that considerable professional demands will be placed on program, technical and procurement personnel in order to achieve a successful second sourcing objective. New problems continually arise requiring creative and innovative solutions. Care must be taken to avoid compromising the Government's position while at the same time complying with the contractor's rights. Second sourcing can frequently be a drain on Government manpower resources with no immediate payoff.

Lastly, in some painfully obvious cases, small, low cost components with extremely tight tolerances may realize large percentage savings due to second sourcing, but low unit savings have not offset the added costs of late equipment deliveries and technical problems demanding Government attention.

In summary, the key word is caution and an understanding that the desired results may be difficult to achieve. Experience has shown that there may be several points in the process where the decision to retain or eliminate the second source may be very crucial. Careful evaluation to either continue or terminate second sourcing effort is essential, as is true with any important procurement decision. It is even more important to realize that second sourcing has limited application in the procurement of major systems and requires thoughtful reflection upon the objectives to be achieved and the methodology for proceeding.

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NEW APPROACHES TO MULTIPLE AWARDED CONTRACTING

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ABSTRACT

This paper presents a descriptive analysis of the role of multiple award contracting in federal procurement practices and possible new directions in its use. The largest (dollar value) of three General Services Administration supply programs, multiple award contracting through the use of negotiated discounts with multiple sources of supply of the same type of product relies on commercial products rather than unique government specifications. Proponents argue that it allows agencies greater variety of choice and brings new products into the supply system faster than other methods. Opponents argue that price discounts are not as good as those produced by competitive bids, that ordering documents are confusing and costly to use, and there is no assurance of minimum quality standards.

Potential changes in multiple award contracting include simplifying basic ordering documents and introducing quantitative and qualitative product information such as life cycle costs. Task forces in the General Services Administration have been set up as a result of December, 1977, action of the Office of Federal Procurement Policy in support of recommendations on commercial products and multiple awards contracting of the Commission on Government Procurement (1972).

LEADER/FOLLOWER PROGRAM - ACES II EJECTION SEAT

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INTRODUCTION

The Leader Company procurement technique described in ASPR Section 4, Part 7, has traditionally been used when the quantity of supplies required exceeds the capacity of a single firm. The technique also makes provision for use in circumstances of scarce special tooling, shortening delivery times, and establishing additional sources for such reasons as geographical dispersion or broadening of the production base. Under the technique, the developer or sole manufacturer of an item (the leader company) furnishes assistance and know-how which enables a follower company to become a source of supply. The pressing needs of national security, such as during wartime, and a determination by the leader company that he is not jeopardizing his status as a supplier are the usual ingredients of past successful leader/follower procurements. There is no record of its use solely to provide for future competition.

There have been some recent variations of the technique directed toward competition by the U. S. Army; one of which was the proofing of the data package by a second source with assistance from the original supplier. This was accomplished in high volume grenade launcher purchases where some question of capacity was present. The Army Missile Command also uses an active program of component breakout with assistance contracts to new suppliers provided by the integrating systems contractor.

The program of leader/follower procurement being utilized for the ACES II Ejection Seat is noteworthy from several aspects. It represents an unique initiative to provide for future competition. It further required a reassessment of motivations, both government and contractor, as they were perceived to operate within the framework of the authorizing regulation. A competitive dilemma exists in procurement programs for sophisticated systems and subsystems. Despite the very real progress made in maintaining competition in development, and even through prototyping, continued competition in production is rarely achieved. The root cause of this condition is the high risk of transferring manufacturing from one firm to another on the basis of reprocurement data. A number of factors contribute to the general inability to successfully use reprocurement data in more sophisticated equipment purchases. These include quality of the data, its timeliness is relationship to program budget decisions and its utility by another firm. By recognizing these deficiencies, the Leader Company technique can serve as a method of augmenting the data, or serve as its replacement.

PRELIMINARY CONSIDERATIONS

Key factors in considering the use of a leader/follower program in the ejection seat procurement were its planned long production run, high front end costs, the availability of initial competition and the ability to evaluate its impact during source selection. The High Technology Ejection Seat program had as one of its primary objectives standardization of new fighter aircraft escape systems. This concept of standardization would provide not only significant logistics benefits and allow large quantity purchases as Government-Furnished Equipment, but also a production run which matched the combined A-10, F-15 and F-16 programs. It was considered highly desirable that such a lengthy production run be subject to continuing competitive pressures. To accomplish this, and maintain standardization, reprocurement of ejection seats identical to the selected design would be necessary. However, given the considerations of high front end costs due to man-rating the seat and the priority of supplying the production lines of three front line fighters, a decision to abandon the proven supplier for another source would be virtually impossible to make. It was also obvious that motivating the selected contractor to participate in a program designed to facilitate future competition would be a hurdle of no small magnitude. In fact, it was only through the competitive forces at work in the initial production competition and use of a structured leader/follower program as a source selection factor that this unique concept survived the "good idea" stage.

IMPLEMENTING GUIDELINES

In addition to having available in a procurement the factors discussed above, certain guidelines were established which study shows would be generally required to implement a competitive leader/follower program. The four considerations discussed in the following subparagraphs were determined to be basic groundrules for a successful program.

a. The issue of contractor proprietary rights or any other legal bar to transferring manufacturing capability had to be addressed. It makes no sense to expend significant effort in embarking on the planning for future competition without clear title to the

design. An assessment during the source selection must be made of restrictions placed on design transfer. The necessity to procure a component or even pay a reasonable royalty for a process to the Leader Company does not necessarily invalidate the program. Such restrictions as well as risks accepted by the government for product liability must be weighed against the objective of future competition. In the ejection seat program, government sponsorship of the competing designs and special attention in the Request for Proposal (RFP to legal rights provisions rendered an acceptable posture for the leader/follower program structure.

b. A reasonable and thorough Statement of Work (SOW) must be established for the follower company. Careful consideration of the effect that the assistance provided by the leader company will have on preproduction requirements is mandatory. If the role of the leader company in preparing the second source for production does not alleviate most qualification costs, the economic benefits of future competition are greatly reduced. The cost of the leader/follower program represents "investment" and must have clear potential of being recovered. This recovery potential is directly proportional to the minimizing of follower nonrecurring costs. By making the leader responsible for quality control and test management, the follower nonrecurring costs were held to $1.5 million. This was not accomplished, however, without several iterations between management and the technical community on a "minimal requirements" SOW. This process must be tempered with enough confidence in the second source s product that the government's willingness to see him replace the leader as the supply source is not hindered.

c. A critical guideline for leader/follower implementation is establishment of a follower source selection plan. The ASPR mandates subcontract approval in 4-702. To be effective, however, in the leader/follower situation designed for future competition, an expansion of this approval to encompass the entire source selection is necessary. This is not a situation with a leader company in a full capacity market. The vested interests of the leader company are presumed to be failure of the follower and must be recognized as such. The selection of the follower must be controlled by the government to assure that the best potential second source is developed. This can be done in several ways: (1) directed by the government based on known capabilities; (2) selected by the leader under acceptable controls: or (3) otherwise selected by the government through competition. Consideration was given to each of these methods. The decision was made to have the follower selected by the leader so that responsibility for performance would be retained by the leader. A source selection plan was required as part of the production RFP and evaluated during negotiations. This plan then became a contractual requirement which the government could monitor. Control of the source selection would be balanced against the exercise of the contractor's judgment. Special care was taken to assure that government personnel acted only as monitors during follower selection. Subcontract approval was issued when it was determined that selection was in accordance with the established plan.

d. The above guidelines were worked out after extensive study, Business Strategy Panel sessions and consultation with the Staff Judge Advocate. The procurement team was satisfied that with a proper RFP, realistic SOW and controlled method of selecting the follower, a viable program could be implemented. There was, however, one glaring hole in this assessment The missing factor was a method of assuring actual implementation by the Leader once selected and awarded the contract for seat production. Traditional positive and negative performance incentives were considered for application to this situation. All were discarded as ineffective. For a positive incentive to work, it would have to offer a reward equal to loss of the firm's future sole source business. Since this was exactly what the government was attempting to attain through the leader/follower program, it made no sense to offer it back as a performance incentive. The most severe negative incentive is Termination for Default. Having agreed to a leader/follower arrangement only through competitive pressures, it was reasoned that termination of the program even for Default would be welcomed by the Leader. Further, any negative action affecting seat production would be a hollow threat due to their need. After exhausting the various combinations and possibilities of incentives between the extremes just described, other intangible motivations were explored. Such considerations as industry reputation, unique program participation and high level Air Force management persuasion were reviewed and also discarded as not practicable. The procurement, legal and policy team decided to go back to the basic motivator of a free market firm, profit. The final profit earned under a contract with a fixed price arrangement is subject to many factors. Most of these factors are under the contractor's control once his bid is accepted and the contract awarded. One factor, contract financing, is assumed by the government and normally not in the firm's profit equation. So long as acceptable performance is maintained, progress payments are made. Their suspension is usually reserved for those situations where performance has deteriorated to such a point that liquidation is doubtful. Therefore, the premise was posed that contract financing could be utilized as a profit motivator.

This would be done by relating all progress payments under the contemplated $60 million contract to a milestone schedule of leader/follower events. This premise was accepted, and a special provision written for the RFP which defined the interrelationship of progress payments and leader/follower milestones.

CONTRACT IMPLEMENTATION

The implementation of the leader/follower program was accomplished as a priced contract line item described by a SOW and definitive performance schedule. Included in the award was the incentive provision and the contractor's source selection plan. Pricing of the line item posed a real challenge to both the contractor and government negotiating teams. Because the Follower subcontractor would not be selected until some nine months after award of the prime contract, it was essentially priced "in the blind." Competition could be relied on to produce effective pricing on the ejection seats, but its validity on the leader/follower effort was in question. There was concern that an unrealistically low estimate would force the leader to abandon the program during performance or seek a price increase which would jeopardize the Air Force commitment to the program. An estimate based on a detailed work breakdown structure of tasks compared to actuals experienced by the competitors during their own development provided the best insight on program costs. Once an acceptable range of risk was established for the subcontract, the contractors' own estimating systems and competition were relied on for the liaison, travel and technology transfer effort to complete the line item cost estimate. The negotiated performance schedule also relied on the competitors' judgments to establish a qualified second producer for the Fiscal Year 1980 procurement. This reliance on the management provided visibility of Leader Company planning and strengthened the enforceability of the incentive provision.

Subsequent to award of the production contract for the ACES II Ejection Seat, leader/follower program activity commenced. Initial actions consisted of RFP preparation by Douglas Aircraft, the selected Leader Company, and its review by a select government team. At times, the role reversal experienced by Douglas personnel in soliciting their own product from competitors was traumatic. However, a competitive source selection, just as planned and scheduled, was completed. The selection was ratified by the government and in September 1977, the Weber Aircraft Company embarked on its role as the Follower contractor of ACES II Ejection Seats.

CONCLUSION

The ultimate success of the program remains to be seen. Current visibility does allow, however, the following comments. The procedures for monitoring the follower source selection worked well and accomplished the government's objectives. There is also evidence that the incentive provision received management attention and has been effective. And, finally, the subcontract price and program costs to date are well within the estimated tolerance band.

While the goal of future competition is a desirable position, many factors must be considered to make a leader/follower program realistic for such a purpose. The projected economic benefits must be weighed against the costs, risks and practicality of the program. Further, there are such issues as the effect of Engineering Change Proposals, timing and extent of future competition and aircraft program changes which must be addressed. The final success of this leader/follower test case will be determined when the judgment can be made that effective competition provided ejection seats of requisite quality, when needed and at costs clearly recognizable as advantageous.

LOGISTICS ACQUISITION

OPTIMIZING TOMORROW'S SPARES PROCUREMENT THROUGH INCREASING AVAILABILITY OF TODAY'S AIRCRAFT*

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ABSTRACT

This paper explores a fundamental cause of aircraft non-availability. It shows that for current Air Force aircraft, a significant portion of the lack of supply availability is due to not stocking items at the base level. Basic research on methods to alleviate this problem in a cost-effective way is reported. It is shown, with specific, real world examples, how these methods can be applied to current inventory aircraft.

I. INTRODUCTION

The Air Force has a sizeable logistics structure to support its many squadrons of aircraft. Two key objectives of this support are (a) to have spare parts and supplies where and when they are needed, and (b) to minimize the cost required to do this. As might be expected, there is a tradeoff between these two objectives. It would be frightfully expensive to stock all parts at every base, so they would always be there when needed. On the other hand, if parts were only stocked at central depots -- a relatively low-cost strategy -- most aircraft would not be operational because they would be awaiting parts to be shipped from the central depot to the bases. Obviously the best strategy is somewhere between these extremes.

The problem is a sizeable one for three reasons. First, military aircraft are so complex that failures of one sort or another occur quite often. Typical flight durations are from 2 to as much as 10 hours, and there are often one or more failures per flight. This results in surprisingly few mission aborts due to the considerable redundancy built into most aircraft. On landing, however, the failed items must usually be repaired or replaced prior to the next flight. This usually requires one or more spare parts to be available at the base or to be shipped from a central depot.

The second reason for the problem being sizeable is the large number of different equipment items and parts on these aircraft. The typical aircraft has about 2,000 work unit coded repairable items; that is, items that can be either replaced or repaired directly at the aircraft location. In addition, there are many additional parts used in base repair shops.

The third reason for the size of the problem is that many of the items are quite expensive, with most unit prices in the range of $100 to $50,000.

How does the Air Force meet this significant logistics problem? At present, "fast moving" items are stocked at both base and depot levels, while "slow moving" items are stocked only at the depot. Under present policy, an item is stocked at base level if there has been either (a) one demand for the item in the last 180 days, or (b) two demands during the last year. Otherwise, the item is not stocked at the base. (An exception occurs when special negotiated levels are established, but this is rare.)

How effective is the current policy? To answer this question, Capt. David Dawson recently analyzed aircraft NORS (Not Operationally Ready -- Supply) downtime using data from the D165B reporting system (see Reference 1). He found that a significant percentage of reported downtime was due to items not being stocked at the base.

Figure 1 shows the results of Capt. Dawson's analysis. As shown in the figure, about 34% of B-52 supply downtime appears to be for items that are not stocked at base level. Similarly, over half of the KC-135 supply downtime hours are associated with such slow-moving items. For A-7D, FB-111A, and F-111 aircraft, about 33% of supply downtime hours are associated with such items.

Capt. Dawson's analysis indicates that non-stockage at the base level is a significant contributor to aircraft supply downtime. The critical question is whether or not it is economically desirable to reduce this downtime by stocking such low demand items at the base.

*A portion of the research reported in this report was funded by the Air Force Office of Scientific Research under Grant 76-3011.

Figure 1: Percent Supply Downtime Due to Not Stocking Items at Base

Aircraft Type	Percent Downtime
B-52	33.9
KC-135	57.2
A-7D	34.7
FB-111A	33.8
F-111	34.7

Specifically, is the value of potential increases in aircraft availability sufficient to justify additional base level inventories?

II. ALGORITHM DEVELOPMENT

In this section, we present mathematical details of a model to evaluate the potential cost-effectiveness of stocking low-demand items at base level. Section III then reports on application of this model to locate specific Air Force items with high benefit/cost ratios. Surprisingly, the special case considered here eventually leads to very simple benefit/cost formulas, even though we begin with the very complex mathematical expressions required to predict aircraft availability. Those readers not interested in the mathematical details should proceed to Section III.

The LMI NORS Model

We used the Logistics Management Institute's (LMI) NORS (Not Operationally Ready -- Supply) prediction model as a starting point for our analysis. This model was developed by LMI as a means of relating the expected number of operational aircraft to alternate Air Force stocking policies. Proofs and other mathematical details for this model are presented in Appendix 3 of Reference 4.

The LMI NORS model may be stated as follows: Let

- N = Quantity of aircraft in the system
- j = the index of a particular component, or item, of the aircraft, $j=1,2,\ldots K$, where K is the total number of items
- c_j = unit cost o component j
- QPA_j = the quantity of component j on one operational aircraft
- s_j = the quantity of spares for component j stocked at a particular location
- $BO_j(s_j)$ = the expected quantity of backorders on component j when the stock level for this component is s_j.

Now let q_j denote the probability that a randomly selected aircraft at a randomly determined point in time does not have any components of type j missing. Mathematically,

$$q_j = \left(1 - \frac{BO_j(s_j)}{N \cdot QPA_j}\right)^{QPA_j}$$

This expression follows from the following arguments: If all N aircraft are to be operational, the total number of units of component j needed is $N \cdot QPA_j$. Recall that $BO_j(s_j)$ denotes the expected number of "holes" in aircraft due to backorders of component j when s_j is the base stock level. Hence, $BO_j(s_j)/(N \cdot QPA_j)$ is the probability that a particular "hole" for item j is empty due to a backorder on that item. Hence, one minus this value is the probability that a given unit of component j is <u>not</u> causing the aircraft to be inoperable. Finally, since each aircraft contains QPA_j units of component j, we must raise the probability that each component j unit is operational to the QPA_j power to determine the probability that <u>all</u> QPA_j units are operational simultaneously. This gives us the above expression for q_j.

Once the component availabilities q_j are known, we may determine Q, the probability that a randomly selected aircraft is operational. This is given by

$$Q = \prod_{j=1}^{K} q_j$$

that is, the probability that a randomly selected aircraft is operational equals the probability that none of its components is in a backorder status. Finally, the expected number of operational aircraft in a fleet of N aircraft is $Q \cdot N$. Hence, the expected number of operational aircraft, ENOA, is given by

$$ENOA = \left(\prod_{j=1}^{K} q_j\right) \cdot N$$

Without loss of generality, we may assume that each item j is numbered in order of increasing demand rates. Hence, ENOA may be written as

$$ENOA = \left(\prod_{j=1}^{J} q_j\right)\left(\prod_{j=J+1}^{K} q_j\right) \cdot N$$

where J denotes the number of items with very low demand rates (e.g. items with demand rates less than 1 demand in 180 days, or .0056 demands/day). This expression may be further simplified to $ENOA = Q^L \cdot Q^H \cdot N$, where Q^L and Q^H denote the first and second product terms, respectively, on the right-hand-side of the above expression. The term Q^L denotes the probability that a low demand item is not causing a "hole" in a randomly selected aircraft, while Q^H similarly denotes the probability that a high demand rate item is <u>not</u> causing an aircraft to be inoperable.

If no backorders ever occurred for low demand items, the expected number of operational aircraft would be $N_o = Q^H \cdot N$. Hence, Q^L measures the impact upon aircraft availability after supply problems for high demand rate items have been accounted for. Combining the above relations, we obtain

$$(1)\quad ENOA = N_o \cdot Q^L = N_o \cdot \prod_{j=1}^{J} \left(1 - \frac{BO(s_j)}{N\ QPA_j}\right)^{QPA_j}$$

If we restrict our attention to items with demand rates of no more than 2 units/365 days or .0056 units/day, and base repair times are in the order of 10 days or less, $BO(s_j)$ will be very small (less than .056 units), even when no items are stocked at the base ($s_j = 0$). Because of this, equation (1) may be greatly simplified. Basically, when (1) is expanded to explicitly represent all terms, we observe that all quadratic and higher terms of $BO(s_j)$ are negligible. Further simplifications are observed when we compute $\Delta ENOA_j$, the marginal change in the expected number of operational aircraft if the base stock level for item j is increased from zero to one unit. Details of this simplification process are presented in Reference 2. The major result of this simplification process is that for low-demand items, $\Delta ENOA_j$ is approximately given by

$$(2)\quad \Delta ENOA_j = \lambda_j T_j \cdot Q^H$$

where λ_j is the daily demand rate for item j, T_j is the average repair/resupply time for item j, and Q^H is the probability that a high demand item is not causing an aircraft to be unavailable.

A Benefit-to-Cost Ratio

Using parameters from the LIST data base (Reference 3),

$$(3)\quad \lambda_j = \frac{\text{Annual Demands}}{\text{Year}}$$

$$(4)\quad T_j = \frac{\text{Downtime Hours Due to Supply}}{\text{Annual Demands}}$$

Hence,

$$(5)\quad \Delta ENOA_j = \lambda_j T_j \cdot Q^H$$

$$= \frac{\text{Annual Demands}}{\text{Year}} \cdot \frac{\text{Downtime Hours Due to Supply}}{\text{Annual Demands}} \cdot Q^H$$

$$= \frac{\text{Downtime Hours Due to Supply}}{\text{Year}} \cdot Q^H$$

Also, since total base NORS rates are typically 5% or less, Q^H should be greater than .95. Also, since there are 8760 hours per year,

$$(6)\quad \Delta ENOA_j = \frac{\text{Annual Downtime Hours Due to Supply/year}}{\text{8760 hours/year}} \cdot (.95)$$

If it is assumed that the value to the Air Force of making one more aircraft available is the purchase cost (unit price) of that aircraft, then the benefit, $BENF_j$, is

$$(7)\quad BENF_j = \Delta ENOA_j \cdot UP_s$$

where UP_s equals the unit price of aircraft type s and where $\Delta ENOA_j$ was previously defined.

The investment, INVST, required to stock one item at each base is simply

$$(8)\quad INVST_j = UP_j \cdot NBASES_s$$

where UP_j equals the unit price of equipment item j and $NBASES_s$ is the number of bases at which a type s aircraft is stationed.

The gross benefit-to-investment ratio is then

$$(9)\quad BTIR_j = \frac{BENF_j}{INVST_j}$$

III. RESULTS

The algorithms described in the previous section were programmed on a CYBER 6600 computer and used to screen through the over 22,000 equipment items in the LIST (Logistics Investment Screening Technique) data base. This data base was developed by personnel of PRAM Program Office, Wright-Patterson AFB, and is described in detail in Reference 3.

The data base contains over 50 key logistics parameters extracted from six different Air Force data systems. The data base encompasses 31 inventory aircraft and over 120,000 work unit coded items. It is based on data for October 1976 to September 1977. While data for support cost, manpower, etc., which is work unit coded, is available on all 120,000 plus equipment items, data on demand rates and unit prices is available only on those items with a cross reference between work unit code and master stock number. At present, only 22,000 of these items are cross-referenced. Although the percentage of cross-referenced items is small, they account for over half of the equipment failures.

Of the 22,000 items cross-referenced in the data base, our analysis indicated that 159 items had a potential benefit-to-investment ratio greater than 25:1. A much larger number of items occur at lower ratios. Also, a more complete cross-reference would increase the number of items which exceed this threshold. Table 1 shows a portion of the results.

TABLE 1

ADDED SPARES STOCKING POLICY ALGORITHM

Aircraft	Work Unit Code	Master Stock Noun	Demand Rate	Annual Demand Per Base	NORSG Hours	Unit Price Equipment	Benefit Dollars	Investment Dollars	Benefit Investment Ratio	Item Manager ALC	CODE
A007D	13AAB	Door	.0026	.715	835.	1324.	285959.	10592.	27.00	OC	BHX
KC135A	14AEO	Panel Ay	.0046	.300	1200.	707.	684932.	22624.	30.27	OC	CTT
F111A	45AAJ	Pump Hand	.0229	1.947	111.	333.	139384.	667.	209.10	OC	NED
C130A	47211	Regulator	.0118	.797	174.	197.	93356.	3154.	29.60	OC	NTD
B052D	41ACL	Valve	.0157	1.005	200.	741.	253425.	3705.	68.40	OC	NTG

A sample of items with an estimated return-on-investment ratio greater than 25:1 is shown. (Note: In these runs, Q^H was set to 1.0). Each equipment item is identified by the aircraft type (MDS), equipment work unit code, and the master stock noun.

The demand rate per 100 equipment flying hours as reported in D-041 is shown next. Knowing the quantity per application (QPA), annual fleet flying hours, and the number of bases, the average annual demands per base are calculated and displayed. Note that this is always less than 2.00. If the demands per base was 2.00 or greater, we assumed the item is stocked at the base, and excluded the item from further analysis. The NORSG hours (annual fleet grounding hours due to supply) is then shown, followed by the unit cost for each item. Finally, the benefit, investment, and benefit-to-investment ratio for each item are displayed. These were calculated using the algorithms presented in the previous section.

To illustrate our results, consider the third item in Table 1. This line indicates that a hand pump used on the F-111A accounted for 111 NORSG hours during the one year period covered by our data base. This item has a demand rate of .0229 units per hundred flying hours, and has an average base demand rate of 1.947 units per year. This item costs $333 per unit, and an investment of $667 would be required to stock one unit of this pump at the two user bases. As shown in the table, if each NORSG hour is priced out at the equivalent cost per hour of a new aircraft, a benefit-to-investment ratio of 209 is implied.

Since erroneous data can creep into the best of data systems, our initial listing only shows potential candidates for additional investigation. It is then necessary to confirm with the item manager that an item is actually a good candidate. To speed this process the item manager is identified by Air Logistics Center (ALC) and item manager code. With the ALC and code, a phone number and name can be easily located on frequently-updated item manager assignment lists.

We called the item managers on over a dozen items. In many cases we found that at any point in time only a few of the bases were actually stocking the item, while most of the bases were not. This would be expected for items with an average demand per base near 2.0. The supply downtimes (NORS hours) were, of course, coming from bases not stocking the item. This indicates that our estimate for the cost of stocking items at the base level is somewhat conservative, since in actual practice, some of the bases would already stock the item.

In several cases we found that the stocks on hand at the depot were sufficient to allow stocking one at each base without any new procurement. In these cases the cost would merely be that of redistribution. There was even a case where the depot stock was excess and destroyed.

On the other hand, we also found a case of improper identification and one discontinued item. While the initial sample check over the telephone increased our confidence in the analytic results, further validation is required before full confidence can be placed in the results.

Another potential problem now being explored is that our cost-benefit ratios are biased in that only items with reported NORSG hours were included in our calculations. Hence, our estimates of NORS-related demand rates are biased upwards. This bias is smallest for items that have a large number of demands across all bases (say 10 or more), but still less than two demands per base, and is largest for the very low usage items. Fortunately, it appears that most of the attractive investment opportunities fall in the higher demand rate categories. Nevertheless, despite the potential bias our results indicate that the formulas described earlier are useful in identifying good candidates for alternate stocking strategies.

IV. CONCLUSIONS AND RECOMMENDATIONS

Our results indicate that the present Air Force policy as to whether an item should be stocked at the base or not, may not be optimal in some cases. This is not, of course, very surprising, as the present policy is based primarily on demand rates and does not usually consider whether or not an item causes aircraft downtime due to supply, the amount of downtime, or the cost to stock the item at the base level.

In some cases it appears that for a relatively small investment, the more glaring discrepancies created by the present policy might be plugged. What is required next is to take specific cases uncovered by our analysis and examine them in detail to determine if the benefits indicated in our analysis are realizeable in the real world. We recommend such an evaluation.

Finally, it appears that in the long term, it might be beneficial for the Air Force to revise its policy for determining whether an item should be stocked at the base or not. In addition to item demand rates, a revised policy should also consider the potential impacts on aircraft availability and the economics involved in stocking the item. The model discussed in Section II provides a mathematical framework from which such a revised policy might be developed.

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THE COMBINED LOGISTICS SYSTEM MODEL: CONCEPT AND IDENTIFICATION PHASE

Major Robert F. Golden, USAF

The Department of Defense presently has a plethora of models available for analyzing logistics support decisions. In the Defense Logistics Studies Information Exchange 1978 Catalog of Logistics Models there are 130 different models listed. [4] These models can be grouped into several categories such as life cycle cost models, maintenance posture models, inventory management models and so on. Each of the models was developed to deal with only one type of logistics problem. Each was developed independently to solve one problem in the overall life cycle of a weapons system. The models are treated as separate entities, when in fact, they are specific segments of the overall life cycle which are often closely related.

The Assistant Secretary of the Air Force for Research, Development and Logistics has suggested that it might be beneficial to determine if the individual models could be combined, and if a combined logistics model would give logistics managers more insight into the operation of the logistics system.

THE TASK

The task of producing a workable combined logistics model is a formidable one which was not attempted by the author. A useful first step is to identify specific models currently in use within the Air Force.

The purpose of the combined model as conceived by the author is first of all to describe the logistics system as it is, rather than as it should be. By being descriptive rather than normative, the model could be of more practical use to logistics managers. Additionally, the model should be designed to be used at the system or program manager level. DOD Instruction 5000.1 clearly places the responsibility for achieving the objectives of the program on the program manager by making him responsible for managing the performance, cost and schedule. [5] A combined model might help the program manager to plan logistics support more effectively.

Paulson and Waina have analyzed the logistics support process, and the weapons system life cycle to identify key decisions and elements. They characterize the following types of models as describing the significant costs and logistics events inherent in a systems life cycle [9]

a. Life cycle cost models.
b. Cost estimating relationship models.
c. Maintenance posture or level of repair models.
d. Spares policy models
e. Personnel models
f. Aerospace Ground Equipment (AGE) models
g. Operations models.

The author's objective was to identify those existing models which might describe the logistics life cycle.

METHODOLOGY

To identify the existing models, current literature consisting of technical reports and management journals of the Air Force and Department of Defense (DOD) were surveyed. The Defense Logistics Studies Information Exchange developed a special bibliography of DOD logistics systems models and provided documents on the various models to the author. Additionally, the offices of primary responsibility for the various models in the Air Force Logistics Command were contacted. As a result, four models which are in actual use within the Air Force were selected, which when taken together include all the significant logistics events set forth by Paulson and Waina: the AFLC Logistics Support Cost Model, the Optimum Repair Level Analysis with AGE model, the Logistics Composite model, and the MOD-METRIC model.

The AFLC Logistics Support Cost Model

The Logistics Support Cost (LSC) Model is an accounting life cycle cost model which is used to estimate the support cost of a specific weapons system or equipment design. LSC is used for differentiating the logistics support costs of competing systems during source selection, and for evaluating design alternatives during prototyping or full scale development. [6]

LSC's major advantage is the depth of cost detail which the model can use. Its major limitation is that the data is often unwieldy because of the detail of inputs and outputs. [3] The model is general in nature and has been used in most new major Air Force weapons systems. Since the model has general applicability it must be tailored for use on specific weapons systems.

The Logistics Composite Model

The Logistics Composite Model (L-COM) is a computer simulation which analyzes the impact of shortages of support resources on the operational status of a weapons system at an air base. [9] L-COM is used to estimate maintenance manpower requirements for Air Force weapons systems, both under development and in the inventory. [11]

The model simulates an actual base operation with support resources and

operational policies defined by the user. The user specifies the maintenance tasks, times, types of missions flown, mission length, etc., to define the scenario. 7 L-COM is flexible enough to meet the needs of different situations. For example, it can process spares on either an item-by-item or a complete subsystem basis. 7

L-COM provides the needed link to relate support cost effectiveness and operational readiness in an operational scenario. For instance, L-COM will track the percentage of missions requested which were accomplished, in relation to logistics resources and levels available. 7 The L-COM program output includes various support and operational effectiveness parameters for the simulated base operation.

The user must input a large number of data elements to define maintenance tasks, operational parameters, and other specific activities, however this information produces useful output information for determining maintenance manpower requirements of a weapons system.

Optimum Repair-Level Analysis

The Optimum Repair-Level Analysis (ORLA) model used in AFLC is a single-item, single-indenture model which analyzes the maintenance posture for a line replaceable unit (LRU) (1: 1-3) It is used to determine whether a spare part should be repaired at the base, repaired at the depot, or discarded at failure. ORLA assumes that cost considerations are overriding in this maintenance decision 1

The user must define parameters which define the operational and maintenance concepts which will be used in the weapons system. Examples include number of squadrons, operational ready rate, and number of aircraft at a base. 1

Items are screened using an iterative process which employs different screening rules to compare the costs of different levels of repair. 1 (2-10) The computer model subjects the final maintenance decision to a sensitivity analysis. 10

The problem of allocating costs of common aerospace ground equipment (AGE) has been addressed in the ORLA computer program, "ORLA with AGE" written by AFLC's Warner-Robins Air Logistics Center. Another limitation of ORLA is that it only addresses the repair decision at the LRU level and does not prove useful for items at lower indentures. 11

ORLA is used for making repair level decisions on weapons systems by all Air Force contractors. 1 This accounting model is the way that the Air Force makes its repair level decisions.

MOD-METRIC

MOD-METRIC is a mathematical model for managing recoverable spares in a multi-item, multi-echelon, multi-indenture inventory system. 8 Unlike other management models, MOD-METRIC is more realistic in that it considers the effects of backorders of shop replaceable units (SRU) and line replaceable units (LRU). 2 A backordered SRU might only delay repair of an LRU while a backordered LRU can ground an aircraft.

Input data for the MOD-METRIC computer models is required on the flying hour program and each recoverable item. Such parameters as item unit cost, mean time between demands and depot repair time are used in the model. 2

The objective of the model is "to determine spare stock levels at each echelon which minimize total expected base backorders for the assembly subject to a constraint on investment in spares." 11 Lagrangian multipliers apportion a budget among the SRUs of a particular LRU and the model optimizes the stock levels of multiple LRU's over the entire inventory system subject to budgetary constraints. 2 This inventory management technique has been used in determining spares levels for the F-15 aircraft.

RESULTS

The four models selected are in common use in the Air Force and therefore represent reality for the Air Force logistics system. They represent how the existing system operates rather than how it should operate.

To determine the synergistic effect of combining the models several steps must be taken. The first is to investigate and define the relationships between the individual models, and resolve any inconsistencies The next step should be to program the combined model on the same computer. The program will integrate the selected models into one interactive model. This will allow the user to change parameters at any time during the program and would enable him to perform such things as intermediate sensitivity analysis during the program.

Finally, the combined model should be tested by using it for logistics planning for a new weapon system. This will enable planners at the program or system management level to obtain a long term view of the system logistics life cycle. The most practical way to assess whether the combined model increases the logisticians insight into the

logistics process is to see what the model can do for personnel actually involved in the process. Actual results of the program can be compared with the model outputs throughout the various phases of the system's life cycle to determine the validity of the combined model.

The combined logistics system model should be applicable to any type of weapons system or even to major systems within the weapons system. By remaining general, the combined model will be more widely applicable and useful for Air Force logistics personnel.

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SPARES ACQUISITION INTEGRATED WITH PRODUCTION

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The Air Force's acquisition of the F-15 Fighter Aircraft incorporated many innovations to improve the logistics posture at a lower cost. One of these was the manner which both initial and replenishment (follow-on) spares were procured. This new process has since been formalized in Air Force Regulation 800-26, entitled, Spares Acquisition Integrated with Production (SAIP). SAIP is, in essence, a procedure to decrease spares acquisition cost through concurrent ordering, production, shipment and pricing of production line installs and spares.

In 1973, aircraft production line cost for an item was compared to the cost for a spare and the significant lower cost for the production line item caused an intensive research program within the F-15 System Manager Division at Warner Robins Air Logistics Center to begin. The finding was the cost differential basically occurred because the spares were bought out of synchronization with the production line requirements. This caused additional production line set up and tear down charges and higher piece part prices for the spares fabrication. If the orders for the production line and the spares could be consolidated and released by the Prime as a single order, the cost differential would, for practical purposes be eliminated. An example of one sub-system is reflected below.

	CASE 1 SPARES PROCURED CONCURRENT WITH FY PRODUCTION	CASE 2 SPARES ORDERED AT VARIOUS TIMES DURING THE PROD YR
FISCAL YEAR	1977	1977
NR OF ITEMS	32	32
NR OF PIECES	303	303
TOTAL VALUE	$1,839,198	$2,381,573
AVG COST/PART	$6,071	$7,860

SUMMARY

CASE 2 COSTS ARE 129% OF CASE 1 COSTS

The System Manager, working in concert with the McDonnell Aircraft Corporation, evolved the procedure currently in use for spares acquisition for the F-15 Aircraft.

There are four specific goals to be achieved:

(1) Fiscal economics, by procuring spares concurrent with aircraft production releases,

(2) No impacts on current Air Force computer systems,

(3) Minimize impact on contractor internal procedures, and

(4) Retain configuration control and proration of assets.

To achieve these goals, a contract must be written having specified parameters. These are:

(1) The prime manufacturer must submit a production line sub-system Purchase Order release schedule,

(2) Proration of assets, when configuration changes occur,

(3) Configuration control,

(4) No early deliveries, and

(5) Unit price integrity

The Government, on its part, must also agree to certain restraints. These are:

(1) Once the basic order is released, the quantities are inviolate,

(2) Any increases will be treated as a separate "stand alone" order and not part of the basic SAIP procurement,

(3) There will be no decreases, instead, these overages will be applied to downstream requirements, and

(4) The only exception to (3) above is where an item is deleted and not replaced or superseded. In this case, the Government will accept termination charges up to date of approval of change, deleting the item.

These features are new in most instances to Government-type contracts, but there are advantages to be realized by both Government and Industry. Implementation of this technique on the F-15 Aircraft has both fiscal and logistics advantages to the Air Force. Logistics requirements are produced concurrently with the installs. There is a simultaneous "cut-in" design change that results in production of properly configured spares. This timely proration reduces retrofit costs.

There is certainly an avoidance of production line "set up" and "tear down" charges with concurrent production of installs and spares. By procuring through the Prime, design changes are documented to aircraft serial number, not vendor unit serial number; "spares support" becomes a more viable criteria for determining the point of design change incorporation. The government receives the benefit of volume pricing by the combining of the spare and production line order. Under the unit price integrity clauses of the contract, the unit cost, once established, is only subject to renegotiation when configuration/design changes affect an item to the extent that it bears little or no resemblance to the item ordered.

The prime manufacturer enjoys advantages, also. Combining production line and spares procurements, the magnitude of the order drives the production line install cost down and he gains the earnings on all the spares orders. Last, the vendor achieves advantages such as one annual order for spares, rather than piecemeal orders throughout the year. He can collectively order piece parts for pricing advantages and the scheduling for manufacturing is very much simplified.

How does this SAIP procedure work in actuality? This is how it was and is applied to the F-15 Aircraft at Warner Robins Air Logistics Center, Robins AFB, Georgia.

The F-15 System Manager, utilizing its data base, isolated those sub-systems where most of the dollars had been spent. Nineteen sub-systems accounted for some eighty-five percent of the spares budget. The determination was made that SAIP procedures would be applied to these systems at the LRU/SRU indenture level only.

McDonnell Aircraft Corporation (McAir) submits their annual Purchase Order Release Schedule to the System Manager, 180 days prior to their first P.O. release. The System Manager, acting as a focal point, submits to the Item Managers, at each of the five Logistics Centers listings of those items which are to be procured under the SAIP technique. They, in turn, send the procurement requirements for these items to the System Manager. The Purchase Request is then prepared and sent to Procurement for Contract Award. The Due-In Asset System is energized and all configuration management of these items is maintained by the System Manager.

Usually, this Purchase Request is released to coincide with the latest requirements computational cycle to ensure the most current procurement requirement is released to production. To date, this timeframe has caused Procurement to award Letter Contracts to meet deadlines of Purchase Order releases by McAir.

These Contract Awards averaged 25 days from date of receipt of the Purchase Request to award of Letter Contract. With this type of document, 100% obligations and lengthy definitization of schedules caused the Air Force to authorize the Warner Robins Air Logistics Center to prepare a specialized Basic Ordering Agreement for SAIP procurements. It contains provisions for:

(1) Priced Orders

(2) Unpriced Orders

(3) Unlimited delegation of authority to WR-ALC Commander to approve priced and unpriced SAIP Orders

(4) Hq AFLC after the fact review

(5) Only WR-ALC can issue SAIP Orders

(6) Multiple pricing methods. FPIS is primary with FPIF and FFP as options, and

(7) All the parameters of a SAIP contract previously discussed.

This BOA gives the F-15 Program the responsiveness and obligation rate desired.

This SAIP approach has proven to be a most expeditious and economical technique for the acquisition of spares. It can be equally applicable to both the Initial and Replenishment area of spares procurements. The F-15 Program has realized the following cost reductions:

\$ 8.0M	-	1974
\$27.0M	-	1975
\$39.0M	-	1976
\$31.0M	-	1977
\$35.0M	-	1978 (Estimated)

Within the Air Force, the A-10 and F-16 Aircraft are utilizing the SAIP technique and the Navy is considering it for the F-18.

RELIABILITY MANAGEMENT INITIATIVES

PROJECT METEOR: MOTIVATING EVERYONE TO ENHANCE OPERATIONAL RELIABILITY/MAINTAINABILITY

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Edward T. Timperlake, The Analytic Sciences Corporation

INTRODUCTION

This paper describes a project that is being sponsored by the Air Force PRAM Program Office in conjunction with the Aeronautical Systems Division (ASD) office responsible for providing program control support to the Deputy for Aeronautical Equipment (ASD/AE). The paper will discuss the macroeconomic trends and DoD directives that provide the impetus for the initiation of a jointly developed program between the Air Force and The Analytic Sciences Corporation (TASC). The developed system is a microeconomic management structure that provides a methodology that has as it's fundamental goal Motivating Everyone to Enhance Operational Reliability/Maintainability of procured systems. (Project METEOR).

The principal elements of Project METEOR include the use of a Life-Cycle Cost concept for selecting production contractors, innovative techniques for testing equipment under simulated operational conditions, and an organized approach to acquiring and evaluating data from program test elements that can be used to help determine projected Life-Cycle Costs for equipment. All of these techniques are used to support the application of contractual incentive features such as the Reliability Improvement Warranty (RIW). The paper will discuss each of these elements of the project and will provide an explanation of detailed case studies where the project elements have been applied.

The case studies to be covered in the paper will include the acquisition of an airborne navigation system referred to as OMEGA, procurement of a standard VHF AM/FM radio for Air Force use, and certain aspects of the current Standard or Common Strategic Doppler (CSD) acquisition program. Although the elements used in all three cases are similar, there are particular differences in terms of the types of procurement techniques used in each program. These differences will be highlighted in the context of the decision criteria and specific procedures associated with the various cost control or incentive schemes. The emphasis will be on the construction of the procurement package with specific discussion centered around the incentivizing techniques that were applied.

The motivational techniques which will be discussed include the Reliability Improvement Warranty (RIW) and organic repair concepts using an MTBF Verification Test (MTBF/VT) concept. The decisions leading up to source selection will be discussed in terms of the use of life-cycle cost estimating schemes and specific procedures associated with the various procurement concepts.

The role which can be played by an independent agent who can provide objective analyses and support will be outlined. Finally, recommendations are made regarding the application of these techniques to future programs.

OVERVIEW

<u>A Need Exists to Reduce O&S Costs</u>: During the last decade DoD has become acutely aware of the challenge to simultaneously: reduce unit acquisition and O&S costs, increase readiness and achieve acceptable military performance. The extent of this challenge is illustrated in Figure 1. Both the Five Year Defense Plan and Extended Planning Annex forecast significant reductions in the ratio of O&S costs as a percent of the total DoD Budget. However, to reverse the historical trend strong corrective action is required. [3]

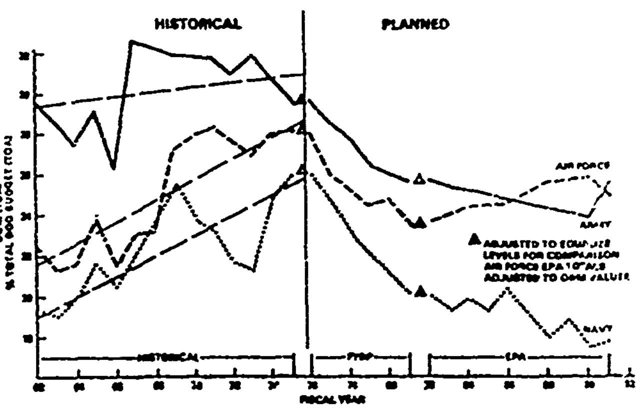

Figure 1 O&S as a Percent of Total DoD Budget

A primary cost driver in the historical rise in the ratio has been increasing manpower costs associated with the less than desired reliability and maintainability characteristics of operational weapon systems and equipment. Therefore, considerable emphasis on reducing costs by improving operational equipment reliability and maintainability is needed. Certain provisions in DoD Directive 5000.28 "Design to Cost" were designed to provide this emphasis. [2] The provisions of 5000.28 of interest in this regard are those that delineate the responsibility of decision makers at all levels in the acquisition community to sharpen their program management tools for analyzing and controlling life-cycle costs. This paper illustrates practical examples of the employment of DoD 5000.28 principles in equipment acquisition activities. It must be noted that life-cycle cost analysis is only a part of the total cost control environment. The use of other techniques and principles to motivate equipment manufacturers to reduce O&S costs are also important.

the following basic principles are typical of those being applied at ASD/AE to provide the basic motivation to produce modern equipment which satisfies requirements to optimize life-cycle cost characteristics: [7]

- Design-to-cost
- System life-cycle cost, projections and controls
- Competitive procurement through the pre-production and production phases
- Improved estimation of program costs and their use in source selection, budgeting, etc.
- Standardization
- Functional system specification
- Reliability Improvement Warranties and LCC Guarantees
- Design for enhanced reliability and maintainability

One of ASD/AE's Solutions: OPLAN METEOR - In the past, equipment has entered the Air Force operational inventory with unacceptable initial reliability. Historically the initial operational reliability of avionics equipment has been only 10% of the specified reliability. This indicated a need for changes to the business strategy which had been employed in the past within avionics acquisition programs. [3]

The Joint-Design-to-Cost-Guide [1:3] defines an acquisition region as a range of acceptable solutions. This range is constrained between certain minimum essential performance parameters which must be obtained for the system to be mission capable, and certain cost ceilings which must not be exceeded for the system to be affordable in the quantities required. It is visualized as follows:

Cost Ceiling

Range of Acceptable Solutions

Performance Floor

Therefore, it follows that a procurement management system that incorporates the previously mentioned macro considerations should provide the decision maker with the ability to intelligently optimize a solution in the acceptable region. Essentially, METEOR provides the program manager, engineers, logisticians, and financial analysts with a coordinated approach to obtaining such an optimum solution. An important issue with respect to OPLAN METEOR is that it is an augmentative management methodology that incorporates a spectrum of motivational decision techniques including a computerized LCC model.

It should be mentioned here that funding for the OPLAN METEOR development work is being provided through the PRAM program office. This office has been created within the Air Force to provide a source of funding and direction for efforts designed to reduce out-year costs. The project is being managed jointly as a PRAM/ASD venture and is a prime example of how up-front funding can be applied to save significant costs in the future.

METEOR CONCEPT

Methodology - The methodological considerations are:

- To apply consistent LCC estimating ground rules
- Motivate Design efforts to reduce LCC
- Test/Independent Assessment of R/M Growth
- Use procurement techniques to promote LCC reductions

An intrinsic element in the methodology is the LCC Model. [6] However, the methodology is far more inclusive than just applying a computerized decision tool such as LCCA. Considerations relevant to design flexibility, system/subsystem performance characteristics, repair level analysis, and manpower staffing requirements are also included. The level of applicability can be expanded and contracted as needed. Since the concept has been used on several programs, the specific procedures are also capable of standing the test of historical validation. This will be shown in the next section when specific case studies are discussed.

The application of the methodology, even in a manpower austre environment at ASD/AE, has had considerable success. The ASD/AE program management philosophy places full accountability on the Program Manager for all aspects of the Program. Part of the success of the concept is related to the fact that it has helped Program Manager's coordinate engineering/design requirements with logistics/cost considerations. This has been done in a way that allows design engineers and financial analysts to communicate with each other about the unique influences that affect cost. A lexicon and an organized approach is provided which both contribute to a common understanding of LCC goals. Various significant spin-off benefits have been noticed from the previous applications. The most signficant is the introduction of LCC considerations at the working level within ASD/AE, thus creating a

cadre of analysts and engineers that thinks in terms of life-cycle costs as well as satisfaction of technical requirements. What has evolved is an organizational memory bank that promotes the use of tested concepts in subsequent equipment acquisition efforts.

Model - The foundation of any life-cycle cost program is an estimate of total program costs which can be used to identify the major cost drivers. Total costs are estimated so that the relative weighting between cost elements is understood. This relative weighting can then be used for tradeoff analysis to determine the lowest overall program cost alternatives.

Early clarification of assumptions underlying the elements of cost is an important step to take in the estimating process. This is enhanced through application of a life-cycle cost model. For most programs the detail necessary to support cost estimating activities can be handled most efficiently if the cost model is computerized. A computerized model also helps clarify the definitions of all terms and input factors. If the cost model is well designed, the engineering data inputs can be designated early in order to promote understanding of the basic assumptions underlying the cost estimates.

A computerized model also makes it easier to keep up with design and program changes as they occur. Program LCCA, the system developed for METEOR and illustrated conceptually in Figure 2, is written in Fortran IV for Operation from remote terminals using telephone access to the General Electric Mark III Time Sharing System. Convenience of operation, file security to protect sensitive data and input-output flexibility are emphasized in Program LCCA.

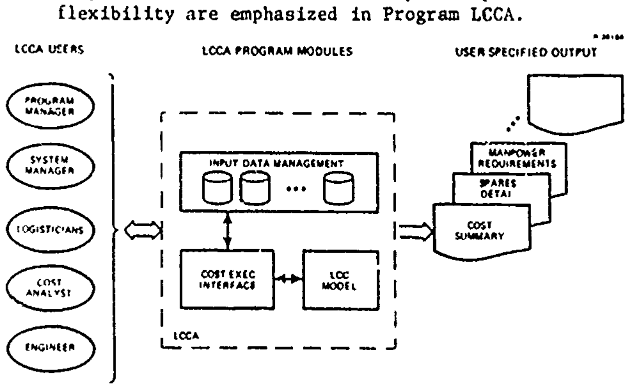

Figure 2 Overview of the LCCA System

Once a baseline set of input files has been established, the effect of changes to any of the input parameters can be readily investigated through the user interface structure provided for this purpose.

Using the baseline files, the analyst can

- Modify program inputs
- Request specific output reports
- Conduct sensitivity analysis.

A nice feature of LCCA in addition to the LCC model is the Cost-Exec interface. The Cost-Exec interface provides a flexible, efficient and convenient user interface to:

- Simplify data entry and program execution
- Allow creation of multiple runs with a minimum of input instruction
- Accomplish tradeoff, sensitivity and risk analysis with a single set of input commands.

The total LCCA system provides the analyst or design engineer with the capability to:

- Identify the major cost drivers during the system's life cycle
- Investigate the sensitivity of life-cycle cost to uncertain parameters (MTBF, repair cycle times, etc.)
- Estimate manpower requirements for logistic support
- Determine spares required to meet specified system availability objectives
- Define test equipment quantities at all levels of maintenance and repair
- Compare the economics of alternative maintenance support concepts including Reliability Improvement Warranty (RIW).

The actual life-cycle cost model configuration will vary according to the system application. Provisions have been made to provide firm configuration control of each variation of the model so that the government maintains control over the relationships used in the LCC calculations. However, there are certain basic considerations that must be noted. The fundamental entity in the LCC Model is the System under investigation. The system is a self contained, identifiable collection of hardware and associated software whose purpose is to perform specified functions. Associated with the system and its application are three basic considerations which form the foundation of the life-cycle cost model. They are the system:

- Hardware Configuration
- Operations and Logistics Scenario
- Life Cycle.

Hardware Configuration - This is defined, in the LCC model to more than one level of indenture (subordination) below the system level.

Operations and Logistics Scenario - This is inclusive of three echelons of repair, the flight line, base or intermediate, and the depot (Government or contractor).

Life Cycle - This is a collection of significant events and time dependent parameters associated with the system's acquisition, operation and support process. The interaction of the system life cycle with the other two basic considerations determines the time intervals in which the different elements of cost are incurred and the magnitude of these costs as a function of time.

Several of the life-cycle cost computations depend on logical relationships established by input parameters that define the support concept for the system. The computation most significantly affected are the base and depot repair costs, the determination of support equipment requirements, and the initial spares determination. Other computational areas of significance are the calculation of life-cycle costs when a warranty is used and, for nuclear hardened equipment, the influence which hardness assurance requirements have on support costs.

Other METEOR Elements - The life-cycle cost model is only part of the concept. In Figure 3 the other elements are shown including the role an independent agent plays. An independent agent not involved in the procurement competition can be used to develop and maintain a data base of information which includes configuration data, test data, and program data from all potential sources. As tests are carried out information is added to the data base. The data base is used to assess reliability and determine life-cycle cost parameters as well as to analyze performance. As equipment is being developed, the data is used with an LCC model to evaluate each competitor's work as the program unfolds. Contractors are continually encouraged to do all they can to minimize life-cycle costs. METEOR also includes the use of innovative test techniques. A Combined Environmental Reliability Testing (CERT) chamber was used on OMEGA program 2041 and is being introduced now within other equipment procurement programs. In addition, new incentive structures are being applied as an option to the RIW. The one used on the VHF radio is called an MTBF Verification Test (MTBF/VT). These and other features will be discussed in more depth in the specific case studies. It should also be noted here that the METEOR Project has as a primary objective the requirement to produce a set of application guidelines that will allow Program Managers to select appropriate elements of the concept for use on future programs. These guidelines will be coordinated with various ASD agencies including the LCC Advisory Group of the Comptroller's Office (ASD/ACC).

APPLICATIONS

OMEGA Program 2041 - The Omega Navigation set was a system conceived to replace the Loran A receiver on C-130 aircraft. So far the program has met performance, and production schedule goals, and use of a highly innovative procurement process resulted in greatly reduced costs. The key factor in the Omega 2041 program was the application of cost reduction principles, later incorporated in the METEOR concept, early in the acquisition cycle. Appropriate parameters were developed, test procedures were designed, engineering data was collected, software evaluation was performed and a LCC model was used to make key procurement decisions. The participants in the OMEGA Program consisted of an Air Force Program Manager, Air Force support elements including engineering (ASD/EN) and procurement support and an independent engineering firm. This coordinated approach proved to be extremely effective in motivating the participating contractors to produce relatively low life-cycle cost equipment which has also proven to be effective in operational use.

The relatively short time between completion of testing activities and the production award required an innovative approach to technical data management. An Engineering Data Base was created, that consisted of computerized files of performance, reliability and operations data. All critical program data was organized and made available for use by the source selection team in time to support the selection process. Manufacturer supplied reliability and reliability growth parameters could be validated using the data base. The success of this constant feedback between manufacturers and the Air Force in the reliability assessment process contributed to a protest-free award of the production contract.

A comprehensive technical evaluation of the software design of each production contractor was also performed. This was done in such a way as to protect each contractor's proprietary interests while still identifying potential problem areas so that corrections could be included in the production design proposals. In addition, the combined procurement team constructed the RIW agreement, solicited contractor feedback and then integrated these requirements with the life-cycle cost procurement approach.

The comprehensive computerized LCC model was used by the Air Force in source selection. The model was also made available for competing contractors use on a time-share facility (GE Mk III) so that all problems associated with cost calculations were resolved in the preproduction program prior to the final phase of source selection. Simultaneously, the Air Force Logistics Command (AFALD) conducted a preliminary trade-off study of RIW versus organic support. However, a definite conclusion was not possible from this study since certain cost factors crucial to the trade off (e.g., RIW price) could not be established with confidence until receipt of contractor proposals. Nevertheless, the study was of value in uncovering the critical issues governing the trade off. Finally, source selection

was made based on lowest evaluated life-cycle cost of qualified designs.

One of the more difficult but interesting questions was the resolution of an RIW vs organic support issue. Since the equipment and program satisfied all other criteria for RIW application as stated in Air Force guidelines, the decision to implement the RIW application or to support the system organically became a question of LCC incentives. While several models were in existence at the time, none included all the support cost elements and the logic necessary to compare RIW to organic support. The cost model was developed and used successfully to satisfy the need to perform these types of analyses.

In summary, it can be said that the production phase procurement action of the OMEGA Program 2041 provided a test case for a new DoD procurement approach. Not all of the elements of the approach were new, but their joint employment in a high visibility program provided a unique opportunity to observe the ability of such an approach to satisfy DoD procurement goals. The important elements embodied in the OMEGA Program 2041 included:

- Design-to-cost-target
- Establishment of competitive prototype development (preproduction) phase
- Qualification of performance and evaluation of reliability of each design prior to production source selection
- Production source selection based on lowest evaluated life-cycle cost of qualified designs
- Election of support option (RIW or organic maintenance) during source selection.

A primary objective of these initiatives which were formalized into METEOR was to reduce life-cycle costs through reliability improvements prior to fielding the first production unit. As a report by the Institute for Defense Analysis pointed out, the need is "to structure a test and fix program which will result in reliability growth ... the test and fix process can be continued after system development but the cost of doing so is substantially greater, often by a factor of 10, than the cost of achieving the required reliability before equipment delivery". [4]

<u>Standard VHF AM/FM Radio</u> - The ability to apply the LCC Methodology in a phased manner was highly evident in the standard VHF AM/FM Radio acquisition cycle. The selected application of appropriate elements of the METEOR t provided for an efficient production s selection process.

A joint AFSC/AFLC life-cycle cost trade-off study, conducted in September 1976, determined that a standard VHF radio which provided both AM and FM modes would be the most cost effective method of satisfying USAF requirements for VHF radios. Based on this study, the use of a new standard VHF AM/FM radio to satisfy the A-10 and F-16 aircraft requirements and for modernizing the current Air Force VHF radio inventory was validated.

The VHF radio program was driven by a critical delivery requirement, namely the need to procure the radio as GFE for initial delivery of A-10 aircraft. To meet this schedule without sacrificing competition, a one-step procurement approach was formulated to competitively select one contractor for award of a firm fixed-priced contract comprised of the following requirements:

- Fabrication and qualification of preproduction units
- Engineering and maintenance support for Air Force conducted DT&E/IOT&E testing
- Fabrication of initial production units for the A-10 and F-16
- Options for follow-on production of up to 9000 units
- Support equipment, spares, training and technical data.

To demonstrate their capability to meet the schedule, potential sources were required to provide certified airworthy hardware with their proposal.

Life-cycle cost was a primary source selection evaluation factor for the standard VHF radio, second only to operational acceptability. The LCC component of the METEOR approach was implemented in the acquisition program. Program LCCA was made available to all potential sources in advance of the RFP package in order for them to gain familiarity with the model and perform tradeoffs for their hardware. Simultaneously, the Air Force, with the support of an independent engineering contractor, developed detailed LCC instructions for inclusion in the RFP package. These instructions identified the acquisition, operation, and logistics scenario data for use by the offeror in exercising LCCA. In addition, detailed groundrules for preparation of offeror provided data were given. The offerors were required to submit LCC proposals consisting of Program LCCA outputs and supporting rationale for all input data used in developing these outputs. By these means, LCC was evaluated uniformly and fairly across all offerors, and the LCC proposal for each offeror was consistent with other parts of the proposal.

As was the case for OMEGA Program 204., the Air Force elected to evaluate both the RIW and organic support options for the standard VHF AM/FM radio. RIW provisions, including MTBF Guarantees, were developed analogous to those used for OMEGA. However, a different approach was required for the organic support option.

Unlike the case in OMEGA, the VHF radio schedule did not permit reliability testing of competitive units. Hence, there was no test data for use by the Air Force to independently assess the MTBFs quoted by the offerors for the organic support option. In addition, with no incentive or control on MTBF, offerors would have no motivation to submit realistic MTBFs for use in LCC evaluation of the organic support option.

Steps, therefore, were taken to put incentives into the organic support option. An innovative provision was developed which eventually came to be referred to as the MTBF Verification Test (MTBF/VT). Under this scheme, the offeror's MTBF quotes submitted in his proposal are later subject to verification in the event he is awarded the contract. The verification is accomplished by selecting a sample of production units and measuring the actual MTBF in operational use. If the quoted MTBF is not achieved, then the contractor must provide settlement spares to the Air Force and an adjustment to contract price is computed to account for the increased cost to the Government associated with the MTBF differential. Initial provisions for the MTBF/VT were drafted and the draft version was provided to the bidders to solicit their concerns and comments. This coordinated version was then subjected to thorough review and revision by program office, contractual, and legal personnel prior to incorporation in the RFP model contract.

Embodied within the RIW and MTBF/VT provisions were formulas for determining the following adjustments in the event that bids were not achieved:

- Consignment spares due to a deficient achieved turnaround time under RIW
- Consignment spares due to a deficient achieved MTBF under RIW
- Settlement spares due to a deficient achieved MTBF in the MTBF/VT
- Contract price adjustment due to a deficient achieved MTBF in the MTBF/VT

Because of the substantial impact on both Government and contractor risk, special precautions were taken to insure that these formulas were appropriate and understood by all parties. Sample calculations in which the formulas were exercised under a variety of conditions were performed and documented. [5] Furthermore, all offerors were required to perform analogous calculations and enter them into the negotiated contract provisions to show their clear understanding of the result should they only achieve one-half their target values. This was to insure that the offeror was fully conscious of the impact of the provisions and to preclude potential claims of misinterpretation at a later date.

Despite the innovative procurement techniques and the requirement to perform the RIW vs organic support LCC trade off during source selection, the tight schedule for the VHF radio procurement was met and a contract was awarded without protest. The continuity and consistency provided by the application of a tested procurement approach, as modified by adaption of the MTBF/VT concept, proved effective in achieving the objective of reducing life-cycle cost without sacrificing specific program requirements.

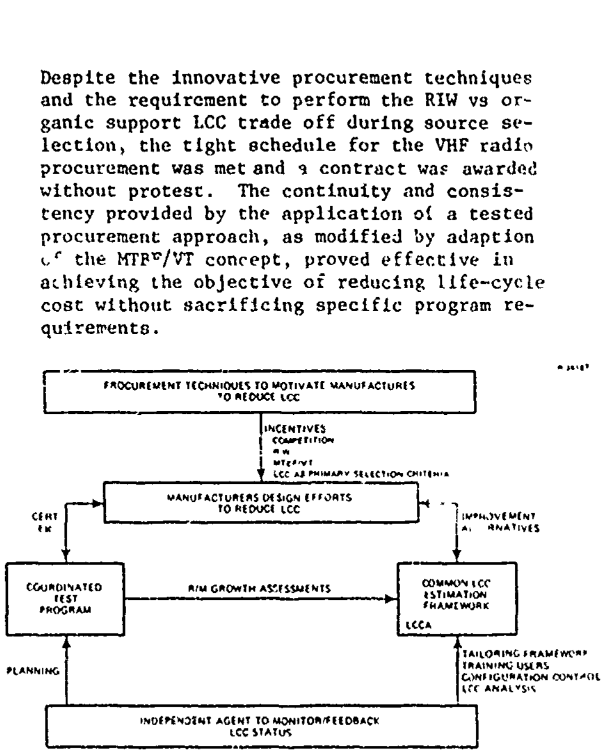

Figure 3 METEOR System Concept

Common Strategic Doppler Program (CSD) - The CSD program is still in the acquisition cycle and consequently, because of proprietary considerations, specific issues cannot be discussed. Rather, some generalized statements can be made about the structuring of the CSD acquisition program that reflect the current state of implementing METEOR concepts.

These concepts are being used extensively in the CSD acquisition cycle from conception to eventual implementation of a Common Strategic Doppler on B-52 and KC-135 aircraft. The original OMEGA 2041 LCC model was chosen as the baseline and then specific LCC requirements incorporating certain considerations relevant to the CSD were applied. For example, the program manager needed cost analyses performed for nuclear hardening considerations. LCCA proved flexible in allowing incorporation of various specifically tailored logical analytic statements in the LCC algorithm. Again as in the OMEGA and VHF situation, an independent agent was used to

- Set up the model (with appropriate specific modifications), provide access by contractors and government personnel, provide use documentation and maintain configuration control (this insured commonality).
- Perform LCC analyses using contractor CSD design inputs.

- Assist with the detailed test planning in order to insure all relevant data is obtained.
- Develop and maintain an engineering data base to collect the results of both the government and contractors' tests on the CSD. In addition, perform auditing and accuracy verification tests on the data to insure it is bias free.

One of the more interesting aspects of the program was the use of an environmental chamber for Combined Environmental Reliability Testing (CERT). The goal was to provide a close approximation to actual flight profiles and realistic simulation of environmental/operating conditions. The chamber was that used on the OMEGA program and the tests were supported by the Air Force Flight Dynamics Laboratory at Wright-Patterson AFB. The experience with it's use prompted the inclusion of CERT requirements in the CSD RFP. Specific test plans were developed by ASD engineers and the data being collected is providing significant inputs into the Engineerin Data Base being maintained for the CSD program.

In addition, a logistics/maintenance concept was analyzed which is a modification between the traditional two or three level maintenance normally performed by the Air Force. This two-and-a-half level support system has an organizational, intermediate and depot maintenance structure in which the intermediate maintenance support for several bases in a geographic region is consolidated in a single shop at a selected base in the region. These CSD studies evaluated the sensitivity of this concept's costs to variations in spares requirements and test equipment costs. A simplified set of RFP response requirements is being developed based on the results of these studies.

CONCLUSION

Avionics equipment helps to maximize the combat effectiveness of aircraft weapon systems. However, avionics also increases both the initial acquisition costs and O&S costs throughout the system life cycle. Failure rates are a serious problem: a system down for maintenance is, at the time, of no more use to the operational commander than a system that was never produced, or a system that was lost in combat. Systems with low reliability and poor quality not only reduce force effectiveness, they continue to drive support cost. Failures and maintenance of avionics equipment account for approximately 52% of all aircraft logistics costs in the Air Force today. Improved reliability and quality assurances are not of sideline interest to DoD. They are central to both the effectiveness and the cost effectiveness of all defense systems.

OPLAN METEOR is a mechanism to help solve reliability problems. As one ASD response to DoD initiatives, METEOR can help both program managers and contractors. It can provide the "front end" leverage needed to reduce life-cycle costs. As previously mentioned the concept contains three basic elements:

- A methodology that provides a structure for design analysis to reduce life-cycle costs. This methodology is supported by early testing and engineering analysis where it can do the most good and is backed up by contractual incentives to improve operational reliability.
- A common and easy-to-use LCC analysis framework tailored for use on each program.
- Procurement techniques that have evolved to help insure life-cycle cost competition is bias free. They include independent agency review, and assessment and feedback of LCC inputs from the test program where appropriate.

The OMEGA program provided the ground work for the formulation of the METEOR concept. In OMEGA the specified MTBF was 500 hours. Prior to pre-production testing it was 30 hours. After completion of testing, growth was measured to 300 hours. Under the provision of the RIW, the MTBF is guaranteed to grow to 1000 hours after 5 years of operational use. With business as usual the life-cycle cost would have been 24.7 million dollars; with METEOR it is estimated to be 15.6 million dollars. The VHF Radio case study illustrated the MTBF/VT concept. More analytical work is required in this area to specifically understand the dynamics of the interrelationship of the testing provisions, sparing requirements and contract incentives that actually motivate contractors to increase the reliability of equipment under the MTBF/VT contract provisions. The CSD is still being developed but the important of CERT is obvious as is the importance of further work with the 2 1/2 level maintenance concept. It is possible that this concept will have advantages over the traditional two or three level philosophies in appropriate deployment scenarios.

In summary, based on the experience to date and enhancements now in process, it appears that contractors can be motivated to enhance the reliability and maintainability of systems being procured today to satisfy tomorrow's requirements. The principal motivators are competition and the knowledge that primary downstream cost drivers, such as MTBF, are to be measured and appropriate adjustments made such as consignment of settlement spares. Obviously, the principles embodied in Project METEOR are not

a panacea for all problems and may not be applicable for all types of programs. The application guidelines being developed for use within ASD/AE will emphasize the modular nature of the methodology so that the widest possible applicability is achieved. It is anticipated that the degree to which these concepts are applied will be a function of the size of the program, users of the equipment being procured (SAC, TAC, ADCOM, etc.), and availability of up-front funds to support multiple sources, independent agency involvement and the pre-production test-fix-test activities where appropriate. After more experience with the concept has been obtained, quantitative guidelines can be developed to assist managers in determining which elements are most applicable for their programs.

The potential for LCC savings has been established. It is now a matter of wider implementation, further refinement of the methodology and evaluation of results to quantify the extent to which LCC cost reductions are actually achieved.

NOTE:

MUCH OF THE INFORMATION IN THIS PAPER IS THE RESULT OF THE AUTHORS' PERSONAL EXPERIENCE WHILE WORKING FOR THE AERONAUTICAL SYSTEMS DIVISION AND SHOULD NOT BE CONSIDERED A STATEMENT OF AIR FORCE POLICY.

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CONTRACTOR INITIATIVES FOR R&M/COST IMPROVEMENT

C. David Weimer

Abstract

This paper presents a synthesis of major findings and conclusions derived from four years research in electronics subsystems acquisition Department of Defense policy statements for achieving improved reliability maintainability, and cost are reviewed The application and implementation of these policies are examined and the management response of system and subsystem contractors is described in areas of operating policies and procedures, project organization, cost management and control, and development program planning The contractor experiences during their engineering development programs are subsequently evaluated in terms of operating problems or policy barriers In total, the experiences of 43 contractors responding in 25 separate programs are examined and analyzed Based upon their past experiences and management behavior, the appropriate response to successfully embrace future policy initiatives is postulated

Introduction

During the past six years, the Office of the Secretary of Defense (OSD) and the Services have been attempting to change the output of the weapons system and subsystem acquisition process In particular, these offices have initiated acquisition policies designed to reduce cost growth and to improve equipment reliability and maintainability. The focus of the policies has been the critical design and development phase, where basic decisions influencing future product cost, reliability, and maintainability are made

Electronics system and subsystem contractors can pursue the objectives of the policies in two primary ways, (1) through the application of new technology which promises greater simplicity, higher reliability, and lower cost per function and (2) through improvements in the planning and management of program activities for reduced cost and higher reliability during development. The planning and management function is believed to be as critical a determinant of program outcome as new technology utilization—there is considerable evidence that the benefits gained through the use of advanced electronics technology have been partially offset by increased performance requirements The results often have been greater equipment complexity, leading to reduced equipment reliability and increased life-cycle cost.

The topic of contractor response to defense acquisition policies can be described in diagramatic form as shown in Figure 1 The figure illustrates the flow of policy directives and subsequent implementing instruction from the government to the contractor organization and eventually to functional organizations within the contractor. Even in this simplistic view of the process, the contractors do not operate in a vacuum Outside influences exist

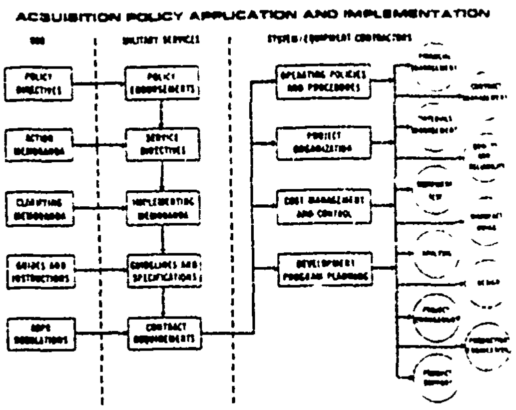

Figure 1 Policy Application and Implementation Framework

ranging from other forms of governmental intervention to the political, economic, and competitive business environment These external forces frequently enter into and alter the form of contractor response This paper will examine some of the key contractor functions illustrated to identify changes which resulted from new policy application

Policy Initiatives

Major DoD policy statements take the form of DoD Directives or Memoranda to Service Secretaries from OSD principals Table 1 lists several recent policy directives and implementing memoranda which are directly concerned with cost, reliability or maintainability

The emphasis of these policy directives has been on cost rather than reliability or maintainability The first DoD Directive 5000.1, established cost as a primary design parameter This launched the DoD Design-to-Cost (DTC) acquisition policy Subsequent directives and memoranda expanded and amplified the original concept

Reliability and maintainability (R&M) objectives usually were contained in the directives as surrogates for support cost goals Where present, they were to be given emphasis equal to acquisition costs Specific policy guidance tailored for R&M has only recently surfaced in the form of draft directives

The major R&M policy initiatives to date have been the establishment of Reliability Improvement Warranties (RIWs), reliability (MTBF) guarantees, and Support Cost Guarantees (SCGs) as contract options to equipment production contracts These require

Table 1 Policy Directives and Implementing Memoranda

ITEM	TITLE	DATE
DoDD 5000.1	ACQUISITION OF MAJOR WEAPON SYSTEMS	13 JULY 1971
(MEMO)	DEVELOPMENT OF PRICE-LIMITED PROTOTYPES	10 JULY 1972
(MEMO)	DESIGN-TO-COST OBJECTIVES ON DSARC PROGRAMS	18 JUNE 1973
(MEMO)	TRIAL USE OF WARRANTIES IN THE ACQUISITION OF ELECTRONIC SUBSYSTEMS	17 AUGUST 1973
GUIDEBOOK	JOINT LOGISTICS COMMANDERS GUIDE ON DESIGN TO-COST	3 OCTOBER 1973
(MEMO)	APPLICATION OF DESIGN-TO-COST MANAGEMENT PRINCIPLES TO SUBSYSTEMS	24 MAY 1974
(MEMO)	TRIAL USE OF RELIABILITY IMPROVEMENT WARRANTIES	14 AUGUST 1974
DoDD 5000.28	DESIGN TO-COST	23 MAY 1975
(MEMO)	DESIGN-TO-COST IMPLEMENTATION	30 SEPTEMBER 1975
GUIDE (REV)	JOINT LOGISTIC COMMANDERS GUIDE ON DESIGN TO-COST	11 [illegible] 1976
DoDD 5000.1 (REV)	MAJOR SYSTEM ACQUISITIONS	18 JANUARY 1977
DoDD 5000.xx (DRAFT)	APPLICATION OF LIFE CYCLE COST MANAGEMENT IN THE SYSTEMS ACQUISITION PROCESS	JANUARY 1977
DoDD 5000.xx (DRAFT)	RELIABILITY AND MAINTAINABILITY OF SYSTEMS AND EQUIPMENT	APRIL 1977

ments emphasize field R&M through equipment performance guarantees. Application of these techniques to new system procurements increased following the 1973 RIW memorandum.

Two new draft policy directives, presently being reviewed prior to issue, deal directly with R&M. They call for methods to predict R&M of proposed systems and consideration of R&M as a major concern during all phases of the acquisition process.

Note that—particularly for DTC policies—several years elapsed between initial policy establishment and more specific guidelines for Service implementation. Refinements incorporating lessons-learned on the initial experiments or trials subsequently resulted in updated and revised policy directives as the concepts matured. To understand contractor response to these policies we will briefly examine the manner in which these policies have been applied.

Policy Application

While the DoD policy directives may be explicit in their objectives and the approach to be followed, changes in the acquisition process and in the management of product development do not occur unless the policies are translated into implementing instructions and contract clauses reflecting the application of the policies to the specific program. No matter how much publicity was given to the new policies the response of many contractors was found to be dependent upon their specific interpretation of current or future contractual commitments.

Since the initial policy statements were published, studies at IDA and elsewhere have been conducted to measure the progress of these initiatives as they were applied to the first candidate development programs. The findings, described below, are of particular interest because they form the basis for explanatory rationale for subsequent contractor behavior.

Design-to-Cost Policies

The contractual requirements for eight original programs designated by the services as price-limited prototypes were analyzed. Key findings were:

1) Seven of the eight price-limited prototypes had entered development *before* being designated as a design-to-cost candidate. At least four of the eight experiments were well into their engineering development programs at a stage where most of the critical design decisions had already been made and approved.

2) Because of the timing, the contractual DTC application for most of the programs resulted in either amended provisions to the initial contract or incomplete contract requirements.

3) A key ingredient of the DTC policy is development program flexibility (cost and schedule) in order to perform design iterations for goal achievement. Only thirty percent of the programs were able to obtain additional time or funds for design iterations.

4) The most inconsistent contract requirement was in the area of equipment cost estimating and reporting. The Government in many cases had little visibility into the status or progress of the production cost management efforts.

Reliability Guarantee Policies

In a manner similar to the design-to-cost policies, the initial programs containing future requirements for reliability guarantees or warranties were analyzed. The findings were parallel. Most of the development contracts did not specify requirements for the future guarantees, terms and conditions were negotiated and finalized during the terminal stages of the development program, at a stage where little development program impact could be realized. Unlike the DTC requirements, however, the finalized contract requirements were generally complete and followed uniform guidelines established by OSD and the Services.[1]

An additional contractual ingredient of the reliability guarantees was the potential financial risk associated with warranty provisions and consignment spare requirements if future field reliability did not achieve predicted values. Contractors found that they were required to price warranties based upon specified reliability and maintainability levels with only limited development program data to predict their ultimate field reliability and warranty cost.

Summary

In the two policies examined, it was observed that translation of broad policy directives into specific contractual requirements took time and was not easily accomplished during an on going and previously planned development program. This was particularly critical when the policy was intended to influence the design of the equipment and the conduct of the development program.

Contractor Initiatives

A primary objective of this paper, and a key output of our previous research, is the identification of contractor response or behavior as a result of the policy directive. It will be several years before the success or failure of the policies can be determined from equipment production cost or field operating performance. Thus, changes in the management or conduct of the development program giving emphasis to policy objectives may be reliable indicators of future policy success. Equally important, problem areas or barriers that prevent policy objectives from being pursued

1 The author believes this can be attributed in large measure [illegible] efforts [illegible] the ARINC Research Corporation played in assisting the Services design [illegible] provisions. Thus the Army and Air Force contract clauses are constructed uniformly and read very much the same.

may be discovered which can be resolved in time for positive benefits to be obtained. Finally, the aggregate experiences of the contractors in responding to these recent policy initiatives should help other contractors or subcontractors formulating development program plans and negotiating contracts containing similar policy requirements.

The investigations into contractor policy response identified several areas where the impact of the DoD policy directives could be observed. Contractors who successfully adopted the new acquisition policies did so through the formalization of their own new or revised operating policies and procedures. This effectively endorsed the new acquisition mode and provided credibility for the internal changes that subsequently were implemented. Contractual requirements, reflecting the new acquisition policies, also led to changes in contractor organizational structures and their internal cost management systems. As the discipline evolved for achieving greater cost and reliability visibility during development, changes were observed in the planning of the engineering development program. These changes required more effort to be spent in several key functional areas. The details of these responses will be examined in the following sections.

Corporate Policies and Procedures

If permanent changes in the conduct of design and development programs were to be accomplished, we expected to find either new or revised corporate operating policies and procedures that reflected the new Government policies. DTC represented a significant change in development program priorities, therefore, some means of legitimizing or authorizing program planning for DTC was anticipated. Our investigation found that sixteen of the twenty-two contractors surveyed had either developed or were preparing new DTC operating policies and procedures. Contractors who were not responsive stated that corporate or divisional directives were inappropriate because of the variety of programs being accomplished or because other existing procedures provided the guidance necessary to respond.

Investigations into the DTC requirements which affected policy establishment identified requirements, illustrated in Table 2, which apparently led to the formalization of the DTC process. All but one contractor who established DTC policies and procedures had requirements for frequent and periodic production-cost estimating, tracking, and reporting. Only half of the contractors without policies were subjected to any cost-reporting, and these requirements were minimal—two reports per program.

Another significant difference found in the contractor requirements was provision for award fees. Most of the contractors with DTC policies and procedures were also working toward award fees based upon their willingness to negotiate a production contract at the product design cost (price). Thus, a causal relationship was found between contract requirements for cost tracking and reporting, contract incentives for achieving production cost goals, and the policy and procedural response of the contractor.

The DTC policies and procedures furnished by eight contractors were examined for characteristics that would indicate scope, level of detail, origin, source of authority, and topics covered. The results of this analysis are presented in Table 3.

The final area for analysis was functional coverage. Functions relating to organizational relationships, cost tracking, product engineering, and production were covered by the majority of contractors. However uniform coverage of cost estimating or validation testing—two critical ingredients in the DTC concept—were

Table 2. DTC Requirements and Contractor Policies

CONTRACTOR CODE	PRODUCTION COST GOAL SPECIFIED	COMPETITION	PERIODIC PRODUCTION COST REPORTING AND TRACKING	AWARD FEE BASED UPON PRODUCTION UNIT COST
CONTRACTORS WITH DTC POLICIES AND PROCEDURES				
B	YES	YES	YES [a]	NO
H	YES	YES	YES [b]	YES
M	YES	YES	YES [a]	YES
Q	NO	NO	YES [a]	NO
R	YES	YES	YES [b]	YES
S	YES	YES	NO	YES
T	YES	NO	— [c]	YES
V	YES	YES	YES [a]	YES
P	NO	YES	YES [b]	NO
CONTRACTORS WITHOUT DTC POLICIES AND PROCEDURES				
D	YES	NO	YES [d]	YES
E	NO	YES	NO	NO
G	YES	YES	NO	NO
J	YES	YES	NO	NO
K	YES	YES	YES [d]	NO
O	YES	YES	YES [d]	NO

[a] Monthly cost reports.
[b] Program milestone cost reports.
[c] Data not available.
[d] Design reviews only (two per ED program)

Table 3. DTC Policy and Procedure Characteristics

CONTRACTOR CODE	ISSUE DATE	APPLI-CATION	AUTHORITY	FUNCTIONS COVERED: [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	APR 74	[illegible]	[illegible]	YES	X		X	X	X	X				X
[illegible]	AUG 72	[illegible]	[illegible]	NO	X	X	X	X			X	X		
[illegible]	JUL 74	[illegible]	[illegible]	YES	X			X		X	X	X		X
[illegible]	[illegible]	[illegible]	[illegible]	NO	X	X	X	X		X	X	X		X
[illegible]	APR 74	[illegible]	[illegible]	YES	X	X	X	X	X	X	X		X	
[illegible]	OCT 73	[illegible]	[illegible]	NO	X	X	X	X		X	X	X		
T*	OCT 73	[illegible]	[illegible]	NO	X	X		X		X	X			X
[illegible]	[illegible] 74	[illegible]	[illegible]	YES	X	X	X	X	X	X	X	X	X	X

* Contractor T issued both division and program policies and procedures.

lacking. Emphasis on subcontractor management or material-purchasing functions were covered by six of eight contractors.

Policies or procedures governing changes to design and development programs for improved or guaranteed reliability and maintainability were not found in our contractor surveys. Based on our experience with DTC policies, this finding was not surprising. In the reliability and maintainability area, specific new reports or program activities were not required by the Government during engineering development. Therefore, changes for increased R&M

responsibility did not have to be formalized, each program manager could take whatever steps he felt necessary to acquire R&M data demonstrate his future product performance, and quantify his potential warranty risk

Project Organization

The second area of policy impact investigated was project organization Several significant organizational changes were found as a result of the new policies The most common organizational response to DTC policies was the addition of DTC staff support to the program manager This response was especially common in pure project organizational arrangements Other contractors created DTC line organizations or specialized DTC engineering staffs All contractors who added to their engineering staffs were organized in a matrix form, each member of the project organization reporting to both their functional supervisor and the program manager

The most influential factors believed to be responsible for the organizational changes were again Government requirements for production cost estimating, tracking, and reporting Ten contractors stated this requirement to be a principal reason for their organizational change Contractors also believed that the emphasis and importance attached to DTC by the Government program offices were primary motivating factors in organizational response Other reasons for change were requirements for life-cycle cost analyses and continuing producibility analyses and planning

Several contractors who reported no formal organizational change responded to DTC requirements through establishment (on a periodic or need basis) of ad hoc DTC committees, or they used existing organizations (e.g., systems engineering) to provide the necessary response

In addition to organization structure, the content of project organizations was found to be influenced by the new policies Significant additions to the project staff were observed in the functional specialty areas of production engineering, maintainability engineering and reliability engineering These functional disciplines were needed to help predict product cost, reliability, and maintainability throughout the development program

Cost Management Changes

As the policy concepts were translated into specific contract requirements, it became necessary for contractors to devote more attention to future production cost during the development program DTC requirements for production cost estimates at the beginning of engineering development and the requirements for periodic updates of the initial estimates meant that contractors would develop capabilities to estimate production cost based upon early conceptual descriptions, track these estimates at detailed levels, and report the estimates to internal management and the Government In order for the design-to-cost goals to be achieved, the cost estimates had to be visible to design engineers on a timely basis This required a time-sensitive management information system that would provide cost estimators with new design concepts and design engineers with the cost estimates of their designs

Cost management changes were also required as reliability warranties and guarantees were introduced as options to be priced prior to production contract award Early in the engineering development program the cost of contractor repair and maintenance had to be considered so that these factors could also influence the design Cost estimates were needed to influence repair or replace decisions during the warranty period And in order to estimate the cost of the warranty estimates were needed for the cost of repair labor and materials the cost of diagnosis and acceptance testing and in the case of guaranteed MTBF requirements, the cost of consignment spares to maintain field availability

The management of future costs during the design phase required that the contractor become proficient in at least three functional areas, cost estimating, cost estimate tracking and reporting, and cost estimate control For many contractor organizations these requirements were new. Contractors were just beginning to implement the latest Government requirements for the management and control of on-going development programs in accordance with DoD Cost/Schedule Control Systems Criteria (C/SCSC) Requirements for future equipment and operations cost estimating represented additional efforts. New management information systems had to be developed and existing capabilities in cost estimating augmented

Development Program Planning

The final, and perhaps the most important area of contractor response, is development program planning and execution In this case, we are concerned with changes made to development programs as a result of the increased emphasis on cost, reliability, and maintainability

As a frame of reference, a functional work breakdown structure for a typical engineering development program has been constructed Figure 2 illustrates the thirteen functional elements which were analyzed during the research.

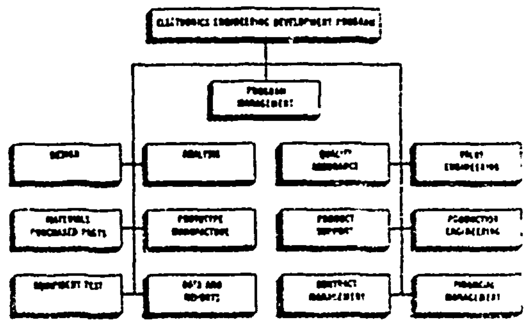

Figure 2 Typical Electronics Development Program Functional Structure

It should be noted that the financial management and contract management functions usually are not directly chargeable to specific programs; they are indirect charges Nevertheless since previous research showed these functions received an impact exhibiting significant responsive changes, they have been included as a part of the development program functional structure

Design

The equipment design efforts were increased for many of the contractors responding to the new policies DTC policies often resulted in several design iterations to maintain or achieve the production cost goals More design effort also was required under policies of potential reliability warranties or guarantees because contractors were required to design their equipment for either field organic maintenance or contractor maintenance The possibility of a warranty also meant designs which ... additional features such as increased built-in test protective ... circuits tamper-proof seals and elapsed time indicators ... perspe

tive the design function received large impacts from both DTC and warranty policies. DTC policies created the largest impact whenever time and funds were available to perform the necessary design iterations

Analysis

Analytical efforts supporting designs also increased as a result of the new policies. New tasks were undertaken to explore alternate materials and analyze additional configurations for lowering cost. Additional effort was found in reliability and maintainability analyses to prepare for possible warranty or guaranteed life-cycle cost obligations. Thus, analytic efforts increased together with the design efforts, the magnitude of the increase was found to be proportional to the timing of the policy application during the design phase

Materials Management

This area was one which received a large impact as a result of the new policies. DTC policies required constant updates of projected production costs that significantly increased communications between prime and supporting subcontractors and vendors. Warranty requirements also caused contractors to take more care with material inspections, certifications of quality control, and in some cases, plant screening and acceptance testing. Contractors also attempted, with very limited success, to pass their new contractual requirements on to lower-level subcontractors. In general, there was a marked increase in supplier communications and in materials screening and testing prior to development use.

Prototype Manufacture

While there had been considerable discussion within the industry concerning the need for larger numbers of development prototypes to support increased design verification and test requirements little, if any, increase in prototyping effort was observed in practice. Possible explanations are that funding for additional prototypes was not available or that most of the development programs were structured without recognizing the need generated by the new policies. Most contractors believed they could benefit from a larger prototype or pilot production program; however, they were unable to obtain the additional time and money required [1]

Equipment Test

This element received a significant increase in effort by those contractors who were preparing for potential warranties or reliability guarantees. In a number of cases, prototypes were subjected to additional tests not specifically required by contract test specifications. The DTC policies were not usually responsible for increased test effort, most of the design iterations were accomplished prior to committing hardware to the major test programs

Quality Assurance

Contractors reported small to moderate increases in quality assurance efforts primarily because potential warranty requirements made it imperative that materials and purchased parts be screened more carefully. Added effort was also expended to insure complete documentation of system and component failures during development testing. DTC policies did not appear to impact the quality assurance efforts except for materials certification and receiving inspection functions

Program Management

The program management element consistently rated highest among the functions that were affected by the new policy requirements. This was not surprising since it is the program manager's responsibility to interpret the requirements of the contractual effort and parcel work packages to other functional organizations. When new policy requirements were applied it was more efficient to add program management staff rather than to disturb an on-going process or a company functional group that is handling many other projects as well. Thus, it was observed that the DTC cost tracking and reporting functions often were assigned to the program manager's staff. The program management staff is also a logical location for multi-functional analyses considering cost, performance, reliability, maintainability, and development program schedule

Financial Management

The response of the contractors in financial management occurred as a result of the DTC policies which, as discussed earlier required product cost estimation at frequent intervals throughout the development program. Additional effort was also noted under warranty policies as management attempted to quantify future financial risks associated with warranty administration. All of the new policies demanded that contractors improve their cost estimating and forecasting capabilities. Because the financial management functional area was most often responsible for providing services or accomplishing this task, their efforts were increased substantially

Product Support Planning

Support planning is a function that ordinarily does not contribute significantly until the second half of the development program when product designs reach the critical design review milestone and support concepts can be specifically linked to the product design. It was found that product support planning began sooner whenever warranty options were a possibility and more total effort therefore was required. DTC impact was found to be minimal except for those cases where life-cycle costs were critical to production contractor source selection

Production Engineering

This function became a significant part of the development process under the DTC policies when producibility concerns affecting production cost became critical. Several program offices augmented their staff early in the development program with production engineering personnel in order that the first preliminary designs would benefit from production engineering visibility. Production engineering also played a role in designing equipment that could be tested, repaired or maintained efficiently under a warranty by the contractor. This function was one of the areas most affected by the new policies.

Value Engineering

Value engineering (VE) was an enigma in our studies. Some firms placed greater emphasis on value engineering during design while others replaced the traditional value engineering function with ad hoc task forces formed to reduce costs. Our analyses indicated that the identification of value engineering with only the specific requirements and incentives of a contract VE clause restricted a broader application of this talent. Thus the overall impact was relatively nominal for each of the policies examined

1 This was especially true for those programs containing development phase competition

Data and Reports

All of the policy initiatives resulted in additional requirements for contractor data and reports DTC requirements surfaced primarily in the form of periodic production cost estimates and cost variance reports Warranty requirements resulted in more detailed data being required from reliability demonstration test programs and planning documents to support the proposed contractor repair or maintenance concept These policies resulted in a moderate increase in effort in this area

Contract Management

As the new policy initiatives were translated into contract requirements, the contract management effort increased Contract clauses calling for cost goal demonstrations and incentive fee provisions resulted in new contract analyses The negotiation of complex and detailed warranty or GSC clauses to be applied to future production contracts also represented a large impact. In most of the programs examined, the formulation and mutual agreement on proposed contractual warranty provisions occupied several months of intensive and sustained effort during the engineering development program

Summary of Development Program Response

The acquisition policies examined in this paper had a significant impact upon the planning and execution of many engineering development programs DTC policies greatly affected the functions of design, program management, materials management, and production engineering while policies leading to reliability guarantees and warranties impacted heavily in areas of design, materials management, equipment test, financial management, program management, and contract management There is evidence that all the development functions were affected by the new policies to some degree.

The relative magnitude of the policy impacts, together with the aggregate impact upon the development program functional elements are shown in Figure 3 It is seen from the figure that the policies contribute to the overall impact in different ways. DTC policies primarily concerned with acquisition cost, complement the warranty impact in the design, analyses materials management, financial management, and program management functions Warranty policies which focus on future operation and maintenance experiences (and cost) dominate the impact in areas of equipment test, quality assurance, product support, and contract management

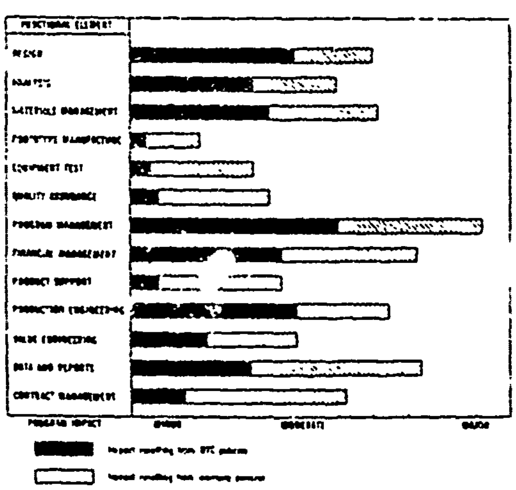

Figure 3 Summary of Development Program Impact

It is difficult to quantify the observed impact in terms either effort or cost. For the warranty policies, our research indicated that those contractors who reported an impact estimated that it resulted in a twelve percent increase in development effort and a comparable increase in cost However only half of the contractors surveyed reported an impact Most of the others reported that program or institutional barriers prevented taking additional development actions It was also discovered that peculiarities of the program or barriers prevented most contractors from responding fully to DTC policies

Contractor Response and Contractor Success

It was not possible to draw conclusive cause and effect relationships between any specific development program characteristic and contractor success in winning the production contract However, the consistent behavior of the winning contractors to these policies is interesting. Sixty-five percent of the successful contractors had formalized the DTC requirements with policies and procedures of their own. While there seemed to be no recurring pattern to the type of organizational structure, in every case except one, production or producibility engineering occupied a major place in the development program organization Cost management also was a strong suit for the winning contractors Another common characteristic was that the successful contractors developed a detailed cost estimating, tracking, and reporting system *independent* of contractual reporting requirements In terms of program element impact, the tabulation of the successful contractors was also noteworthy. There was a three-to-one difference in effort reported between successful and unsuccessful contractors in almost every category examined. It is not clear whether other program characteristics such as technical performance may have been more important determinants of success than contractor response, but it is believed that the contractors who strongly embraced the intent of the policy initiatives were in a more confident posture when the production RFP arrived

Barriers to Contractor Response

The contractor response observed for the recent acquisition initiatives was usually not optimum to pursue or achieve the policy objectives. It was commonly observed that the potential for a greater or more effective response was present, but institutional or program-unique barriers prevented this from occurring The problem areas or policy barriers encountered, listed in order of their reported frequency, are shown in Table 4 below

A full discussion of these and other program-peculiar problem areas is beyond the scope of this paper However some general observations related to contractor response are worth mentioning

A recurring problem observed in many of the cases examined is that the expected policy outcome is often based upon the premise that the acquisition environment is favorable or can be easily modified to accommodate the new policies Examples of this are (1) the expectation that there will be additional time and money available in the development programs to iterate equipment designs in order to meet pre-set design cost goals (2) the expecta

Table 4. Policy Barriers and Problem Areas

BARRIER OR PROBLEM	PERCENT OF CONTRACTORS REPORTING	POLICY IMPACT: DESIGN-TO-COST	POLICY IMPACT: RELIABILITY GUARANTEES
SCHEDULE RESTRICTIONS	85	MAJOR	MINOR
COST ESTIMATING UNCERTAINTIES	82	MAJOR	MODERATE
COST PERFORMANCE TRADEOFFS	80	MAJOR	MINOR
ECONOMIC PRICE UNCERTAINTIES	72	MAJOR	MINOR
SUBCONTRACTOR/VENDOR MANAGEMENT	68	MAJOR	MAJOR
SPECIFICATION FLEXIBILITY	60	MAJOR	MAJOR
DEVELOPMENT FUNDING	60	MAJOR	MINOR
POLICY CREDIBILITY	56	MAJOR	MAJOR
POLICY REQUIREMENTS UNCERTAINTY	42	MINOR	MAJOR
CONFLICTS BETWEEN POLICIES	40	MAJOR	MAJOR
RELIABILITY PREDICTION	35	MINOR	MAJOR

tion that the development test programs will provide realistic indications of expected operational reliability and maintainability, and (3) the expectation that new policies can be readily converted to contractual requirements and will instantly implement fundamental changes in contractor behavior. These expectations were never fully realized in the programs analyzed.

Another problem area we found was that related policy concepts are not usually compatible whenever output priorities conflict. A policy calling for fixed price guarantees of reliability, maintainability or support cost will not be easily integrated into a DTC program whose firm unit production cost targets have already been set without R&M or life-cycle cost considerations.

Finally, the policies we've studied are designed to fundamentally change the way systems and subsystems are developed and acquired. In order for these changes to occur, the need for change must be clearly recognized and the benefits for change must be clearly visible. These are ingredients of policy credibility, which for many programs, has been less than desired. If the contractor perceives a lack of credibility, policy response will be reflective and fundamental changes will not be implemented. In this case, credibility (or the lack of credibility) becomes a barrier to implementing change.

Future Development Program Planning

Based upon what we've observed for these recent policy initiatives and the subsequent contractor experiences and response, there are several lessons-learned that could aid contractors in future development program planning.

The first lesson-learned is that successful contractors took the initiative, interpreted the intent of the policies, and translated policy intent into operating practice in advance and independent of Government contract requirements. This procedure was risky and increased financial exposure during the critical early development period. Successful contractor behavior during the development program was not unlike that of companies who were developing products for the commercial sector. However, institutional arrangements effectively blocked a full commercial response.

The second lesson-learned is that these new policies can be implemented much easier if major barriers to their execution are recognized. The following conditions should be present for new acquisition policy success.

1) The Government program office must firmly believe in and endorse the policy.
2) The policy must be appropriate to the development program under consideration.
3) Sufficient time should remain in the development program to accomplish the goals of the policy.
4) Flexibility should be incorporated as part of the program to reverse previous decisions if the new policy requires a changed product design or development program.
5) Contractual requirements for policy application must be analyzed and agreed-to at an early stage.
6) Areas of policy interference with present program policy and planning should be analyzed and resolved.
7) Additional funds, if required, should be available to execute the development program in accordance with new policy guidelines.

The major lesson-learned is that policies aimed at reducing total product life-cycle costs will probably require more time and effort during development than otherwise would have been expended. Basic development engineering disciplines such as design, analysis, test, and evaluation, together with program management will be affected. Indirect functions such as financial management, materials management, and contract management may also require more effort to properly analyze and implement the policies. Ways should be explored to efficiently expend these valuable front-end dollars which can have great leverage on the cost and outcome of the total program.

Conclusion

Contractor response to recent acquisition policy initiatives was examined. It was found that new policy application to the initial programs often was only partially effective because of improper timing and delays in policy acceptance. Nevertheless, significant contractor responses was found in areas of policies and procedures, organizational structure, cost management, and development program planning. It was found that beneficial contractor response usually required more development time and effort. The potential for a greater and more effective response was identified if institutional and acquisition environment barriers could be attenuated or eliminated.

Changes in contractor behavior leading to improvements in system and subsystem cost, reliability, and maintainability are difficult to implement exclusively through new policy initiatives. Positive contractor response will depend upon many factors ranging from the perceived credibility of the Government to the successful accommodation of policy barriers contained in the present acquisition process.

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Biography

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Dr Weimer is a management consultant specializing in R&D program management and cost analysis for the aerospace and military electronics industry His professional background includes eight years as a Senior Research Staff Member with the Institute for Defense Analyses (IDA) and 13 years engineering and program management experience in the aerospace industry, principally with the United Technologies Corporation. At IDA, Dr Weimer conducted analyses and consulted for numerous OSD and Service organizations in the fields of reliability and cost. He was a member of the Fubini Defense Science Board Avionics Task Force, a participating member of the Army Material Acquisition Review Committee, and a project director for the OSD-sponsored Electronics-X Study. During the past few years he directed original research programs in the areas of Design-to-Cost, reliability warranties and guarantees, and development program planning for cost and reliability goal achievement His industrial assignments included positions as a test engineer, instrumentation engineer, development engineer, project manager, and program director in the fields of propulsion development and missile guidance and control He is also presently associated with the George Washington University as an Associate Professor in R&D management and public administration.

Dr Weimer holds a B.S in physics from the University of Pittsburgh, a M S in management from George Washington University and a D B.A in management and finance, also from George Washington. Other graduate studies include course work toward an M S in mechanical engineering He currently is a member of the AIAA, IEEE, AAS, and the Academy of Management.

FAILURE MODE AND EFFECT ANALYSIS AND RELIABILITY IMPROVEMENT

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ABSTRACT

There is a strong link between the essential aspects of Reliability Improvement Warranties (RIW) and those of Failure Mode and Effect Analysis (FMEA). Clearly, it is the failure of a system which will cause down-time, require logistical support, and generally increase the costs and support efforts required to support the RIW. The evaluation and elimination of failure areas early in the acquisition process, through a comprehensive and thorough Failure Mode and Effect Analysis, can result in a RIW which fulfills its purpose. A new analytical tool known as the Failure-Criticality Grid is presented which can provide management and engineering more insight into the value of FMEA in establishing the various aspects which comprise a RIW. FMEA and the associated Failure-Criticality Grid, although not panaceas, are valuable tools which can enhance the value of reliability improvement.

INTRODUCTION

Failure Mode and Effect Analysis (FMEA) is a systematic approach to the analysis of the capabilities and performance of a system with respect to the areas of its possible failure. In contrast, a reliability analysis is concerned with the probability that a system will operate successfully within defined specifications over a specified period of time. Essentially, the FMEA is a deterministic analysis because it makes the basic assumption that the system has failed, regardless of the results of the reliability analysis. Then, the FMEA proceeds with a hypothetical determination of how the system failed, known as the Failure Mode, and the effect that this failure will have on the system capabilities and performance, known as the Failure Effect. Currently, this analysis is carried out through the entire system structure from the overall system level to the lowest level of individual components.

The purpose of this report is to analyze the important aspects of Failure Mode and Effect Analysis, relate them to reliability improvement and, consequently, Reliability Improvement Warranties. It examines the structure and use of the FMEA Failure-Criticality Grid, a new tool which, when associated with the full FMEA, enables the condensation of the full depth of the information of the FMEA and presents it in a form which is clear and easily evaluated.

THE CURRENT ROLE AND FMEA

Failure Mode and Effect Analysis is a potentially valuable tool for the acquisition manager and reliability engineer. However, an extensive year-long study of the current role of FMEA in reliability improvement, conducted by the author, has shown that the use of FMEA as an effective management tool is hindered by the current philosophy which surrounds the process. This philosophy has resulted in procedures which tend to continue to limit the scope of FMEA utilization and which contribute to the developemnt of FMEA as a process which becomes increasingly separated from management.

Currently, FMEA is primarily a reiteration of the quantitative determinations of the reliability analysis. In order for the full benefit of the FMEA process to be realized, FMEA must become divorced from the numerics of the reliability analysis because its full potential lies in its ability to provide information for qualitative management decisions. It is recommended that the reliability improvement process include a FMEA which makes use of a technique which associates failure probability and failure rate data with a predetermined set of ranges. These ranges allow more flexibility in the decision making process because the dependency of the FMEA upon specific numbers is reduced. This technique is addressed here as the FMEA Failure Criticality Grid.

FAILURE MODE AND EFFECT ANALYSIS

A system operates, or fails to operate, based upon the performance of certain critical components or subsystems. The key in evaluating the ability of the system to perform a required mission, or achieve a desired objective, is the identification of these critical areas. Many times, the design of a system is so complex that a simple examination is not sufficient for this identification process. The Failure Mode and Effect Analysis is a systematic method of identifying and classifying these critical areas and, subsequently, gaining an insight into the feasibility and extent of reliability improvement efforts.

The failure mode is the manner in which the component, subsystem or system has failed. The analysis also involves a consideration of the failure cause, or that situation which results in the failure mode. Also it is necessary to determine the effect which the failure mode has on the system, or on those components or subsystems directly related to the failed item. In order to improve the effectiveness of the analysis and make readily apparent the seriousness of any one particular failure mode. Each failure effect is classified by its criticality to the overall system performance. This criticality classification

primarily follows the guidelines of Table 1.

TABLE 1

CRITICALITY CLASSIFICATIONS

CLASS		
IV	CATASTROPHIC	Any single failure which could potentially cause the complete loss of the system, or cause death of injury to personnel.
III	CRITICAL	Any failure which could potentially cause any of the following: 1. The function or mission of the system to be aborted without loss of equipment or endangering personnel. 2. A condition which although enabling the system to function, could become more serious. 3. A hazardous condition which is repairable during system operation.
II	NON-CRITICAL	Any failure which degrades the performance of the system and results in the function or mission being aborted or the loss of any automatic control capabilities.
I	MINOR	Any failure which does not degrade the performance of the system, any type of failure other than those of Class I, II, or III, which requires corrective action.

A Hypothetical System

The value of the FMEA lies in its systematic approach, and by using the preceeding definitions it is possible to establish a sequence of events for the development of a FMEA. First, the system being analyzed must be fully identified as to its nomenclature, function and composition including a description of the associated subsystems. In addition, it is necessary to identify those associated subsystems which are to be excluded from the analysis. For our purposes, we shall identify the system being analyzed as a high pressure air compressor which will, hypothetically, be used to supply all the high pressure air for a varied number of operation. This system is a modification of that presented by Stump (1) in that it incorporates a more comprehensive indenture level identification scheme. The compressor will be an electric motor driven two cylinder, four stage piston type with closed, or recirculating, water cooling and self-contained lubrication. Excluded from the analysis will be the power controller and the high pressure storage tank. Figure 1 shows the block diagram for this system, which breaks the system into its functional areas, such as motor and compressor, and clearly shows the inputs and outputs of each functional area. Therefore, it can be easily seen that the motor supplies torque of 4610 revolutions per minute (rpm) to the compressor, the cooling and moisture separation, and lubrication stages and that the compressor supplies outputs of high pressure air and of pressure and temperature signals to the instrument and monitor stage. Although not included in the analysis, the relationship of the electrical control stage to the over-all system is also shown.

Each of the major functional areas may also consist of functional sub-areas, and in a complex system this chain of interrelationships may be quite complex. Therefore, the next step of the analysis is to establish some means for the identification of the level of these relationships, or the indenture level. The first indenture level is that of the complete compressor system and will be indicated by '0'. The second level is that of the major functional areas, instrumentation and monitors, compressor, motor, lubrication, and cooling and moisture separation, and these will be numbered, respectively, 0.1, 0.2, 0.3, 0.4, 0.5, as shown in Figure 1. The third indenture level consists of those subsystems which comprise each of these major areas. The breakdown for the instrumentation and monitor stage is shown in Figure 2. Each of the subsidiary block diagrams follow the same concept in that they must completely identify the subsystem function, show the input and output relationships, and be clearly associated with the next higher level diagram. This system can be easily extended to the full depth of any system, as shown in Figure 3 which illustrates the breakdown of the temperature monitor subsystem numbered 0.1.4 in Figure 2. A unit designated by 0.1.4.1.4 can be readily identified, in a top-down analysis, as belonging to the major system

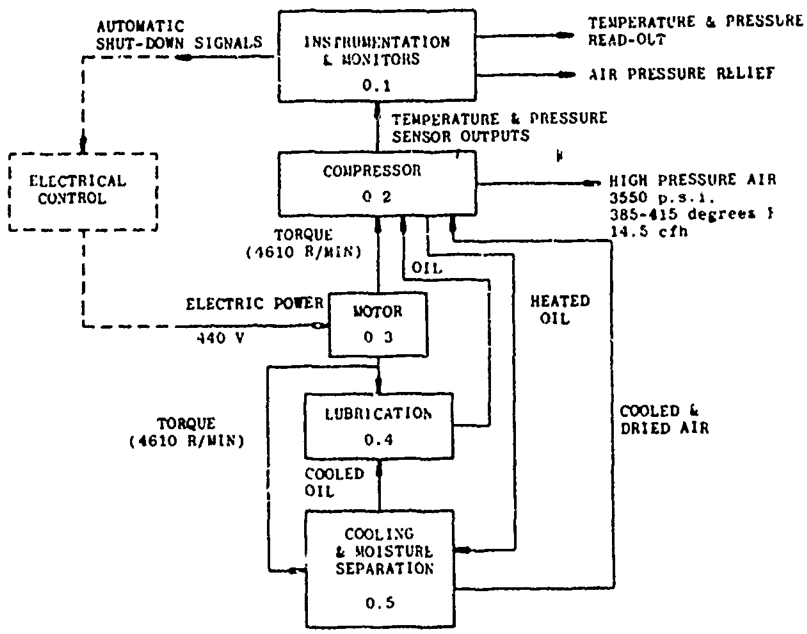

Figure 1 System Functional Block Diagram
Second Indenture Level

0., or the compressor system major functional area 0.1, or the instrumentation and monitor stage, subsystem 0.1.4, or the temperature monitor, subunit 0.1.4.1, or the temperature sensor for the air inlet, and finally to unit 0.1.4.1.4, or the fourth stage air inlet temperature sensor. In addition, this indenture system allows each input or output signal or function to be precisely designated. The signals for each individual unit can be numbered consecutively and entered as a dashed number in the indenture level number. For example, the oil temperature signal shown in Figure 2 would be designed as 0.1.4-3, indicating that it is signal number three for unit 0.1.4. Although the system arrangement seems somewhat complicated, in practice it is quite simple to master and affords the analyst a brief and precise method of itemizing and accounting for each unit and signal within a complex system.

The Failure-Criticality Grid

The format and content of a FMEA done by one contractor differs in form and content from that of another. However, most contain either an entry for failure rate or failure probability. Both of these factors are derived from the information in the reliability analysis but have subtle differences. Failure probability is the probability that a failure will occur during a specified interval of time and failure rate is the frequency at which failures occur over a specified interval of time. Failure probability is usually expressed as a number between zero and one and failure rate is normally expressed as the number of failures occurring per unit operating hour. This type of information is generally beneficial because it provides some degree of correspondence to the likelihood of the occurrence of a failure mode. The question arises, however, of how this information can be effectively employed in assessing the progress of the system development, establishing trade-offs with respect to the factors of cost, schedule and performance, determining the dollar impact of changes, or establishing a reliability improvement program.

The Failure-Criticality Grid, shown in Figure 4, is a modification of that used by Stump (1) in that it more effectively

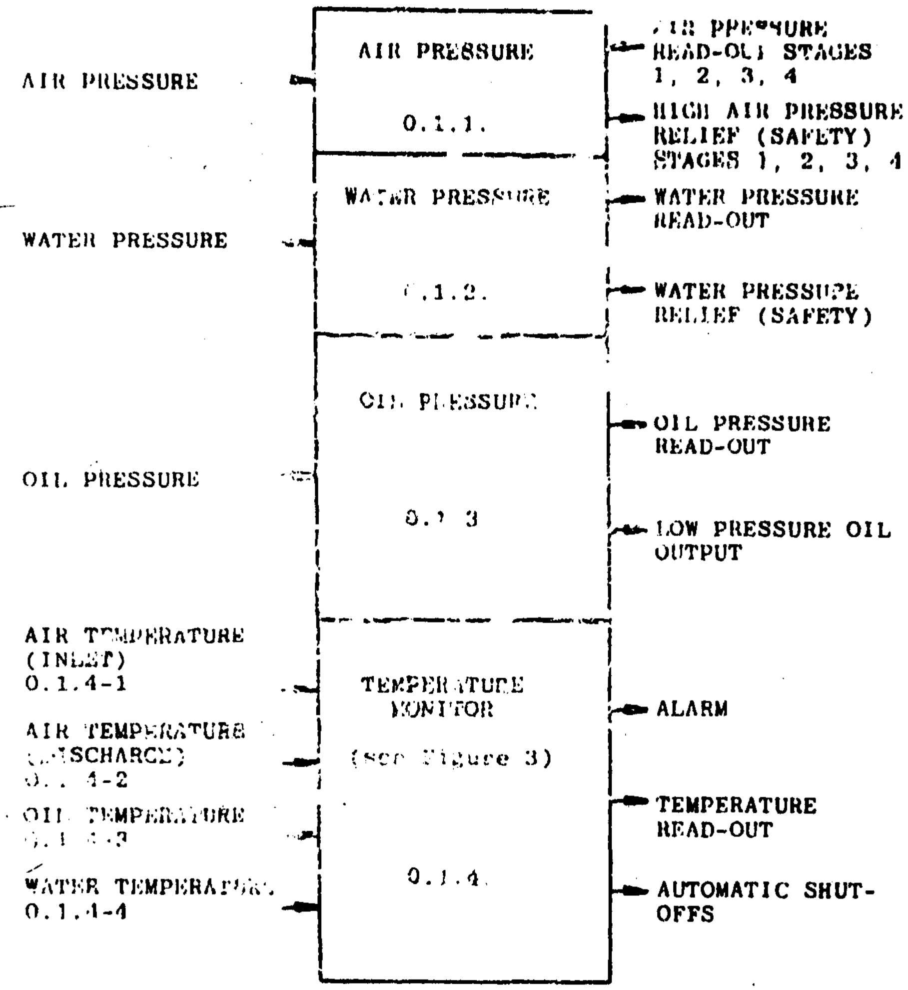

Figure 2. Instrumentation and Monitors
Third Indenture Level

incorporates the previously stated definitions. The Failure-Criticality Grid is intended to provide a method which will allow the acquisition manager and reliability engineer to easily visualize the relationships of failure probability or failure rate and criticality classification. This can be especially beneficial in efforts in determining the capability of the system to meet specific design goals and objectives allocating resources to critical areas of the procurement effort, establishing the impact of design changes, and in determining the progress and maturity of the system development. The Failure-Criticality Grid uses a technique of stratifying the failure probability or failure rate information into designated ranges. It must be emphasized that the following discussion employs failure ranges which are for example only.

Stratification, as used in the formulation of the Failure-Criticality Grid presented here, is the process of dividing the probability space into different ranges when using failure probability data. (1) For failure rate data, the area of stratification could, for example, cover from zero failures per unit time to the

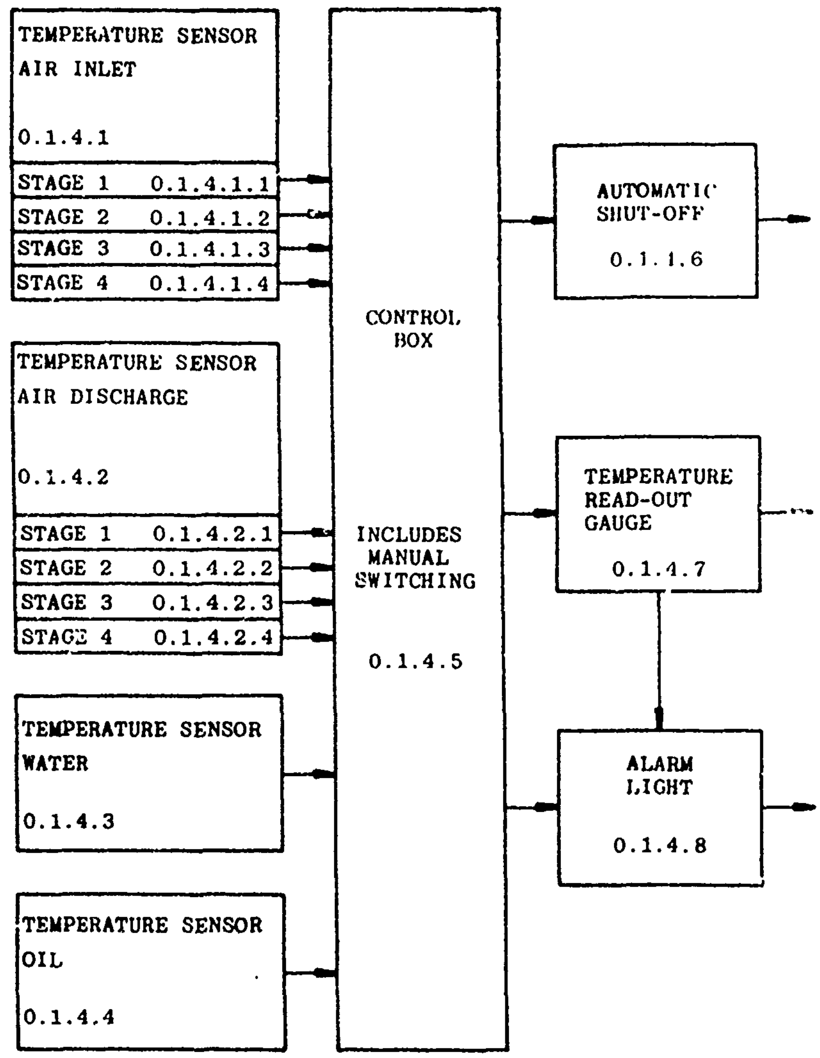

Figure 3. Temperature Monitor
Fourth Indenture Level

maximum specified failures per unit time. The ranges are flexible and can be adjusted in size and number according to the system specification and the requirements of the program management. The stratification shown in Table 2 is used for the sample Failure-Criticality Grid presented here. Again, it must be emphasized that the failure ranges, failure probabilities and failure rates used herein are for example only. In actual use in a procurement effort, these factors would be based upon the specification and the requirements of the particular program.

The Failure-Criticality Grid is a method which can be employed to quickly and efficiently determine the relationship of the criticality classification and the failure range, as determined by the stratification

CRITICALITY CLASSIFICATION	1	2	3	4
IV	0.1-2 0.1-3 0.2-1 0.2-1 0.2-2 0.4 0.5 0.5 0.1.4-3			
III	0.2-1 0.3 0.3 0.3 0.4 0.5 0.5 0.1.4-2		0.1-1 0.1.4-1	
II	0.2-1 0.1.4-2 0.1.4-3	0.1-3		
I	0.1-1 0.2-2	0.2-1	0.1-2 0.1.4-1	

FAILURE RANGE

Figure 4. Failure-Criticality Grid

technique. As entries are made in the Grid, the distribution of the failure modes, speci-ed by unit and signal reference number, become apparent. The Grid shown in Figure 4 is for the system shown in Figure 1 The vertical axis represents the failure ranges obtained after stratification. Each failure mode is then assigned to its respective location in the matrix based upon these two factors, and is designated by the indenture level reference notation described earlier.

Due to its size and complexity a FMEA accomplished with current techniques is extremely difficult to analyze with respect to the relative occurrence of any single criticality classification and the distribution of all criticality classifications over the entire

TABLE 2

STRATIFICATION OF FAILURE RANGES USED IN THE FAILURE-CRITICALITY GRID

RANGE	
1	Failure probability which is less than or equal to 0.01; very low. Failure rate of one or less failures per year.
2	Failure probability which is greater than 0.01 and less than or equal to 0.10; low. Failure rate of more than one failure per year and ten or less failures per year.
3	Failure probability which is greater than 0.10 and less than or equal to 0.20; medium. Failure rate of more than ten failures per year and twenty or less failures per year.
4	Failures probability which is greater than 0.20; high. Failure rate of greater than twenty failures per year.

system. The Failure-Criticality Grid clearly fulfills this need. The primary benefit of this method is the immediate visibility of the entire system development.

If a reliability engineer should establish the goal of reducing the number of Category III and IV failures, as well he should, the Failure-Criticality Grid offers him a vehicle with which to measure the success of his effort. In addition, he can determine the change in status of the failure modes for the entire system. For example, if a design change were implemented to eliminate the Category III-Range 3 failure mode, referenced by 0.1-1 in Figure 4, and this change resulted in a shift of this failure mode to Category IV-Range 1, the change would be obvious with the use of the Grid. Current FMEA procedures require that a large portion of the FMEA would have to be analyzed before such a change would be apparent. The Grid of Figure 4 shows a large cluster of failure modes in Category IV-Range 1. Perhaps an acquisition manager might want to allocate resources to change this situation. Under current practices, this grouping of failure modes would be hidden in the complexity of the FMEA. Nearly every occurrence which changes the criticality classification or failure range of a specific failure mode is made clear through the use of the Failure-Criticality Grid. In addition, the impact of such a change upon the entire system configuration is readily apparent. Essentially, the Grid can provide the acquisition manager and reliability engineer with increased visibility of the procurement effort and result in increased managerial efficiency. The benefits to be derived from the use of the Failure-Criticality Grid can be directly applied to a comprehensive program of reliability improvement.

The advantages of the Failure-Criticality Grid in enhancing the reliability improvement of an acquisition effort are apparent. First, it provides the reliability engineer with a clear and concise presentation of the major system problem areas. Additionally, it shows the distribution of these critical areas through the full range of criticality classifications. If the reliability engineer is careful in the structuring of the stratification of the failure probability or failure rate, data, the data takes on added meaning by clearly showing the relationship between the criticality classification and the failure data. The Failure-Criticality Grid can also be employed by the acquisition manager in his efforts to properly allocate resources to the system development. Critical areas which demand priority attention are no longer buried in the complexity of the FMEA and become obvious. Most importantly for the purposes of reliability improvement, the Failure-Criticality Grid provides a vehicle for evaluating the changes which occur due to design changes made in response to reliability improvement requirements. By showing the distribution of failure modes across all major subsystems, the impact of reliability improvement efforts become obvious. When used in conjunction with the Failure-Criticality Grid, the FMEA takes on increased value and cost-effectiveness.

The reliability of the system is a factor which must be considered throughout the entire acquisition cycle. Clearly, if the system is not reliable then its feasibility for fulfilling the defense objective is negated. The impact of design changes the types and distribution of failures, the causes and effects of failures, the symptoms and detectability of failures, and the interrelationships of subsystems are all factors which influence reliability. Accordingly, the FMEA, and its associated Failure-Criticality Grid, are methods by which each of these factors can be assessed. However, this study has found that little use is made of the FMEA in this context. A great deal of the information which is used to evaluate the maintainability of a system is drawn from the reliability analysis because of the numerical determinations made for such factors as mean-time-to-repair (MTTR), mean-time-between-failure (MTBF), mean-time-between-replacement (MTBR), maintenance downtime (MDT), and total turn-around time (TAT). The FMEA is not structured to provide the calculations for these factors, and it should not be.

However, the FMEA can provide the information needed to make a qualitative evaluation of reliability improvement because if does show the relative impact of design changes, and emphasizes those areas of failure which can cause significant maintenance problems. The Failure Mode and Effect Analysis also shows the subsystem relationships involved in the system and can indicate the existance of problem areas which may not be apparent by the numb r alone.

SUMMARY

Failure Mode and Effect Analysis and reliability improvement are closely linked. Through a description of a hypothetical compressor system, the fundamental components of a FMEA have been considered. This description has been oriented toward a description of the make-up and use of a new analytical tool, known as the Failure-Criticality Grid. The Grid, when used in conjunction with the FMEA, offers the acquisition manager and reliability engineer a valuable vehicle for the clear and concise presentation of the data contained in the FMEA, and enables an efficient evaluation of the effectiveness of reliability improvement efforts.

The true validity and cost effectiveness of the FMEA process lies in its capability to be applied to a diverse number of areas of the procurement effort. This study has found that the current structure of FMEA and the general philosophy surrounding its use have acted as deterents to its being employed to its full potential. This is especially true in the broad area of reliability improvement. A change in the current philosophy, and the subsequent change in the procedures, can result in a wider use and acceptance of FMEA. As the scope of FMEA use increases to cover more aspects of the procurement effort, its validity and cost effectiveness increase.

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SELECTED TOPICS IN

ACQUISITION RESEARCH MANAGEMENT

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PROCUREMENT/ACQUISITION RESEARCH AND THE CIVIL AGENCIES

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INTRODUCTION

In a September 30, 1977, General Accounting Office (GAO) report, entitled "An Organized Approach to Improving Federal Procurement and Acquisition Practices," it was reported that:

> "Today a program of organized research into Federal procurement and acquisition practices does not exist on a government-wide basis or within an executive department. The present pattern of research efforts by executive agencies is mixed, ranging from no program to a few efforts in DoD." (11:2)

The formalization of procurement/acquisition research within the Federal Government had its start within the Department of Defense (DoD) approximately eleven years ago. One of the recommendations of the Defense Procurement Pricing Conference held in Hershey, Pennsylvania, in November 1967, was to establish a DoD procurement research laboratory. Although this recommendation was not implemented, individual DoD components moved to set up formal procurement research organizations and, recently, DoD initiated a program to establish a research planning system by organizing the DoD Acquisition Research Council (ARC). On the civil agency side, there have been no formalized programs to the extent of establishing agency procurement research centers or organizations. However, there has been, and continues to be, procurement research accomplished and/or sponsored by several civil agencies. Much of the significance of this research is being lost or overlooked due to a lack of understanding and a clear definition of what constitutes procurement research.

BACKGROUND

In order to understand the state of procurement research in the civil agencies, it is first necessary to review briefly the history of procurement research in DoD and the other forces and organizations leading to the present.

In January 1969, following the recommendation of the Hershey Conference, Secretary of Defense Clark Clifford, in his prepared statement regarding the 1970 Defense budget and Defense program, proposed that a procurement research laboratory be established. Later, a House Committee on Government Operations report (House Report No. 91-1719, December 10, 1970) stated that:

> "The rationale for Mr. Clifford's proposal, we surmise, is based on the consideration that so much of procurement research today is done essentially on a fast-reaction basis, in response to immediate problems, with short-term results. Innovations or improvements which do come about are not necessarily brought to the attention of other procuring activities. Similarly, improvements which may be developed in industry or in the academic world may be missed. Even where innovations see the light of day, there may be long delays before they are exploited by the Defense Department's many procuring activities or agencies. A procurement research laboratory in our opinion would:
>
> Identify and exploit new and significant business methods;
>
> Develop, test, and innovate procurement methods on a systematic and centralized basis;
>
> Effect coordination of such efforts within the Department of Defense;
>
> Test or simulate the impact of major new policies and procedures on government activities and industry prior to their issuance;
>
> And provide an in-house consulting and training capability to hasten the exploitation of significant developments."

Although the idea of a DoD procurement research laboratory--in several forms--was discussed, including use of the Logistics Management Institute, different views among the services postponed indefinitely any unified effort. While the above events transpired, the Army established its Procurement Research Office (APRO) in 1969. Subsequently, the Air Force organized the Business Management Research Center (AFBMRC) in 1973; the Navy its acquisition research program in 1977 (presently being restructured); and the Defense Systems Management College (DSMC), also in 1977, initiated a formalized program of acquisition research.

External to the DoD efforts, in 1970 Study Group No. 5, Organization and Personnel of the Commission on Government Procurement (COGP), discussed procurement research during its

series of civil agency visits, and found that some agencies did not favor internal agency research. This was due, in some instances, to an agency's low volume of procurement and, in other cases, because the agency felt that:

- ad hoc management studies, in lieu of formal research programs, are more effective in solving their problems;

- an agency program would impose an undue burden on its resources and could result in research duplication; and

- a joint interagency or government-wide approach is more economical and realistic for meeting agency research needs. (1:758)

In its final report, the COGP recommended the establishment of a "Federal Procurement Institute" and listed its responsibilities in the field of research as follows:

"Conduct and sponsor research in procurement policy and procedure. (This function would encompass the concept of the 'Procurement Research Laboratory' as discussed in House Report 91-1719, December 10, 1970.)

"Establish and maintain a central repository and research library in the field of Federal procurement and grants.

"Offer a program, similar to Sloan Fellowships, for Federal and industry personnel. This program would provide a period of study and research at the Institute or related institutions.

"Maintain liaison with professional organizations; participate in intergovernmental and international procurement conferences and related activities." (2:52)

The Commission's report and subsequent interagency task group reports to establish an executive branch position on the Commission's recommendation stated th .:

"/as the DoD research/ centers will stress DoD procurement, it appears that a gap exists insofar as procurement research in other agencies is concerned. The Work Group believes this gap should be filled. As DoD can best meet its own research needs, it should proceed with its present plans and actions. Other agencies should also be encouraged to conduct their own research in the procurement field. The FPI should conduct or sponsor that research which is of Government-wide interest or which is beyond the scope of individual agencies. It might also conduct research relating to a particular agency at the request of the agency concerned. The FPI should also coordinate the planning and implementation of procurement research conducted or sponsored by the various Federal agencies to avoid duplication or overlapping." (5:8)

The next milestone in the evolution of procurement research (and one of the most significant) occurred with the establishment of the Office of Federal Procurement Policy (OFPP).

Public Law 93-400, enacted on August 30, 1974, established the OFPP in the Office of Management and Budget (OMB) to provide overall direction of procurement policy and to improve the economy, efficiency, and effectiveness of the procurement of property and services by the executive agencies. The creation of OFPP as the focal point for Federal procurement policy implemented the first recommendation of the Commission on Government Procurement.

Public Law 93-400 set forth six functions for the Office of Federal Procurement Policy and, although only one is directly concerned with procurement research, all are paraphrased below due to their interrelationship:

1. Establish a system of coordinated and, to the extent feasible, uniform procurement regulations.

2. Establish criteria for soliciting the viewpoints of interested parties in the development of procurement policies and regulations.

3. Monitor and revise policies relating to reliance by the Government on the private sector to provide needed property and services.

4. Promote and conduct research in procurement policy matters.

5. Establish a Government-wide procurement data system.

6. Recommend and promote programs for recruitment, training, career development, and performance evaluation of procurement personnel.

For the first time, as a result of the Act, there is a statutory responsibility to promote and conduct procurement research. Although the Act does not describe or define procurement research, the legislative history of P.L. 93-400 makes it clear that Congress viewed the responsibilities of OFPP in a broad sense, encompassing the areas covered by the 149 recommendations of the COGP. Taking the Act and the legislative history into consideration,

it is obvious that the scope of "procurement research" can be considered in a very broad context, including the full range of functions and activities of the OFPP.

In July 1976, Hugh Witt, the first Administrator for Federal Procurement Policy, established the Federal Procurement Institute (FPI) by a "Memorandum to Heads of Executive Departments and Agencies," which set forth the following objective for procurement research:

> "promote, monitor, and conduct research to develop business methods and management techniques that will advance the state-of-the-art in procurement."

The establishment of the FPI was later endorsed by a "Memorandum of Understanding and Plan for Sponsorship, Organization and Operation of the Federal Procurement Institute," originally signed by 20 agencies during 1976 (24 as of April 1978). This MOU reiterated the above research bjective, stating that:

> "...the FPI will be the focal point for coordinating the Government-wide planning, development, implementation, and evaluation of programs in the areas of procurement research, education and training, and career development."

It further stated that the FPI would work in cooperation with the participating agencies, the Civil Service Commission, and the OFPP in carrying out its stated objectives.

THE FEDERAL PROCUREMENT/ACQUISITION INSTITUTE AND PROCUREMENT RESEARCH

On September 9, 1977, Dr. John J. Bennett was sworn in as the first Director of the Federal Procurement Institute (changed to the Federal Acquisition Institute as of March 1, 1978), and plans were immediately initiated to structure a procurement and business research program as one of the Institute's primary functions (the other primary areas being education and training and career development).

One of the first steps taken by the Federal Acquisition Institute (FAI) to build its research efforts was to hold a Procurement and Business Research Planning Meeting on October 27, 1977, to initiate the development of a "Federal Procurement and Business Research Planning System." Attendees from OFPP, the Department of Energy (DOE), the Department of Housing and Urban Development (HUD), and the four DoD procurement and acquisition research centers met informally to discuss OFPP and FAI research roles, review DoD experience, discuss civil agency requirements, and to consider a broad FAI approach to research planning. One of the most significant things to come out of this meeting was the definition of the role of OFPP and FAI, made by Mr. LeRoy Haugh, Associate Administrator for Regulations and Procedures, OFPP, who has the responsibility for procurement research within the Office of Federal Procurement Policy. Mr. Haugh characterized the role of OFPP in procurement research as one of policy making and program initiation, and that the FAI would act as its operational entity in accomplishing specific research programs.

As a result of this meeting, Air Force representatives agreed to draft a research guide with Army input and DSMC assistance. The four DoD centers, OFPP, and FAI agreed to meet in late November to begin to prepare a five-year annual plan, using the elements of a planning system prepared by the FAI as the initial framework.

The first plan was to represent the aggregate of requirements, projects, and funding for the six participants and to provide the procedural basis for future growth. The FAI agreed to devote one man-year of effort to determine civil agency research needs that would be merged into a government-wide plan at a later date.

The second procurement and business research planning session was held on November 29, 1977, where attendees from three DoD procurement and acquisition research centers, the Experimental Technology Incentives Program (ETIP) of the National Bureau of Standards, National Aeronautics and Space Administration (NASA), HUD, and DOE took a first cut in structuring a five-year procurement and business research plan based upon real and perceived reser h requirements.

In December 1977, the Acquisition Research Council (ARC) was formed within DoD. The ARC is chaired by Mr. Dale Church, Deputy Under Secretary of Defense (Acquisition Policy), and includes acquisition executive officials from the Office of the Secretary of Defense (OSD) and the military departments, as well as the Commandant, DSMC, and the Director of the FAI. In the two previous planning sessions, the FAI had met with representatives from the DoD procurement and acquisition research centers. Under a new arrangement discussed at the first ARC planning session, the FAI was now to work jointly with and through the DSMC, who would act as the executive agent for DoD acquisition research.

The Acquisition Research Council then held its first meeting under the direction of its chairman, Mr. Church, in January 1978. Representatives from the Army, Navy, Air Force, Defense Logistics Agency (DLA), DSMC, and the FAI attended, and discussions were held on the proposed membership and organization of the Council. The Council's planning

arm at the military department level, the "Acquisition Research Coordinating Committee," also held its first meeting in January, and the Director, FAI, will be a member of both organizations. The DoD is currently circulating a draft directive (DoD Directive 4105.68, dated March 10, 1978) which describes the procedures, responsibilities, and membership of both the ARC and its coordinating committee.

PROCUREMENT RESEARCH AND THE CIVIL AGENCIES

Paralleling the initial planning research efforts of the FAI and the establishment of DoD's ARC, the GAO report on procurement research, "An Organized Approach to Improving Federal Procurement and Acquisition Practices," dated September 30, 1977, was sent to Congress and distributed throughout the government.

In the report, the GAO related that procurement practices have become so important in the scheme of Federal operations that large government agencies--such as Defense, Energy, Transportation, NASA, and GSA--depend upon systems, products, and services obtained from private enterprise to do their job. These activities cost about $70 billion annually and involve about 60,000 Federal workers. (11:i)

The GAO report also pointed out that:

- over the past 30 years, procurement has become more complex;

- efforts to solve problems have resulted in a complex patchwork of laws, methods, regulations, procedures, and administrative requirements; and

- not all the old problems have been solved and new ones continue to arise.

As to procurement research, GAO related that both the House Government Operations Committee and the Commission on Government Procurement recommended a continuing program of research to make Federal procurement practices work better and to design and test the best ways to carry out new policies; i.e., using a scientific approach to improving Federal procurement.

The GAO also found that:

> "Currently, there are no procurement research programs in some agencies. In others there are a few relatively new ones.
>
> "Civilian agencies generally are reluctant to undertake procurement research. Within some quarters of DoD, procurement research has been going on for about 6 years. Even so, the general condition is one of insufficient momentum.
>
> "Some agencies expect the newly emerging Federal Procurement Institute to carry this burden. The institute is only now being established, however, and will take some time to become operationally effective. Even then it will not perform research roles for the individual agencies." (11:i-ii)

In view of its findings, the GAO recommended to OMB the establishment of a strong program for procurement and acquisition research on a government-wide basis. As part of this program, those agencies dependent upon procurement and acquisition processes to carry out their primary responsibilities would be required to establish a continuing research effort to assure effective procurement and acquisition.

As envisioned by the GAO, such a program would enable agencies to:

> "o Correct and refine procedures on a continuing basis and cope with procurement problems peculiar to particular agencies as the difficulties arise.
>
> "o Evaluate agency experiences in procurement and acquisition, achieve innotative improvements, develop training materials and participate in research of a government-wide nature."

Additionally, GAO discussed various uses of such research and set forth a framework for organizing and operating a procurement research program, setting forth:

> "o Definitions of the procurement research function both narrow and broad.
>
> "o Basic prerequisites for operating the program.
>
> "o Roles of participants, including Federal agencies, the Federal Procurement Institute, and the Office of Federal Procurement Policy.
>
> "o Considerations in screening research needs, selecting projects, conducting the research itself and evaluating results.

In response to the GAO findings, Mr. Lester A. Fettig, Administrator for Federal Procurement

Policy, stated in a letter to the General Accounting Office:

> "The Office of Management and Budget shares your concern that not enough attention has been devoted in the past to research of procurement problems. The summary of research activity now being carried on, and the framework for an expanded program suggested in your report, will be useful in promoting a Government-wide program.
>
> "In the second paragraph of the digest, you state, 'In retrospect, the improvements have not been forthcoming due, in part, to the lack of strong and sustained agency research efforts to get at root causes and make breakthrough improvements.' I have no doubt that a strong program of procurement research will result in significant improvements, but this should be coupled with operational implementation considerations." (11:48)

As a next step, Mr. Fettig, in a letter to Dr. Bennett dated February 14, 1978, designated the Federal Acquisition Institute to be the focal point, particularly for the civil agencies, to follow up on the GAO report. At the same time, Mr. Fettig, by a memorandum also dated February 14, 1978, requested civil agency FAI Policy Board members to designate a procurement research representative to attend an initial procurement research planning session and to continue serving as their agency's focal point in working with the OFPP and the FAI.

The first civil agency procurement/acquisition research planning session was held on March 2, 1978, and chaired by Dr. Bennett. The group was addressed by Mr. Fettig, who stressed the importance and benefits that would occur from an organized program of acquisition and procurement research. After considerable discussion, the attendees, representing fifteen civil agencies, unanimously agreed to constitute the group as a "Civil Agency Acquisition Research Council" and to organize and develop a charter as an FAI Interagency Specialized Work Group (ISWG). During the discussions on a proposed charter, it was agreed that the council's primary focus should be initially one of better communication and coordination among the agencies in the research area, and that the role of the FAI would be to operate the organizational mechanism, coordinate activities between the DoD ARC and the council, and provide research support for the council and its agencies. In addition, the council would recommend specific projects and recommend a research budget for these efforts.

During the ensuing discussion, it became evident that there was a need for definitions, and the ETIP representative agreed to take on a short-term project to provide a working definition of procurement research and to define appropriate policies for conducting such research. At this point, Mr. LeRoy Haugh, OFPP stated that in DoD they tried not to narrow down definitions of research since they did not want procurement research to become too esoteric and removed from real problem areas. He further stated that DoD procurement research was a systematic approach to problem solving; which is what we are aiming for here rather than trying to force the development of formal research organizations on the civil agencies. The next planning session of the council was set for April 7, 1978.

If the first civil agency research planning session could be characterized as one of guarded optimism, the second session, held on April 7, was by contrast quite enthusiastic. The second meeting was also chaired by Dr. Bennett and attended by representatives of 15 civil agencies, OFPP, FAI, and one observer from the DSMC.

The first order of business was for each council member to discuss procurement and business research in their respective agencies. Since ETIP, NASA, and DOE have on-going research projects, their representatives had been requested to prepare more extensive briefings than the other members, and they led off the discussions. Since this paper is concerned with procurement/acquisition research in the civil agencies, the following is an agency-by-agency summary of their briefings and remarks:

<u>ETIP, National Bureau of Standards, Department of Commerce</u>.

The ETIP procurement program objectives were listed as twofold:

- o To determine if government procurement can, through the use of procurement incentives, stimulate private sector innovation.
- o To develop a framework which relates the use of incentive techniques to agency, product, and industry characteristics.

The strategy employed is to:

- o Conduct procurement experiments with partner agencies that test particular incentives.
- o Document and evaluate results.
- o Make policy recommendations.

On-going programs, products, and involved agencies were:

[illegible]	[illegible]	[illegible]
[illegible]	Appliances	GSA
[illegible]	Furniture	VA
[illegible]	[illegible]	DOD
[illegible]	Computer	HEW
[illegible]	Health Care	DOT
	Automotive	HUD
	Hardware	

The ETIP Research Process was discussed, and the fo'lowing outline of the process was presented:

o Identify the decision maker	Who cares?
o Obtain information needs	What will it take to convince you?
o Preliminary feedback	What will happen?
o Design	What data do we get? Who gets it?
o Implement	Make the change
o Evaluate	What happened?
o Recommendations	

The ETIP approach to Procurement Research was given as: A systematic approach to problem solving. Assumptions: (1) Currently not enough information to make a decision; (2) final product of research effort will be a decision.

NASA (Prepared remarks were furnished by the NASA representative.)

Although NASA has not had a formal program for conducting procurement or acquisition research, we have been informally performing research to support our acquisition process since our very earliest days. Some of i~ has been evolutionary and stimulated by t' more general growth of our profession. And some has been directed by the challenge of the features of our Space Act and the unique role it provides NASA as we interface with the private sector.

We prefer to distinguish between procurement basic and applied research. Both carry the traditional definition. That is, it is a studious inquiry or examination aimed at the discovery and interpretation of facts, revision of accepted theories or laws in light of new facts, or practical application of such new or revised theories or laws. Basic research is considered to be in the nature of social science study while applied research is the technology or systems design growing out of basic research.

The Comptroller General's report to the Congress (PSAD-77-128, September 30, 1977) made it very clear that it is important to add some formality to our research program. With more formality, we will have an opportunity to maximize the results of our research and we achieve a positive means through which we can identify related activities being conducted by others. Although the report expresses a concern relative to independent agency research since it tends to "fractionalize and duplicate effort," we have been performing procurement research and plan to continue to do so. To the extent that our efforts can be molded with the efforts of others such as the members of this Council and the Federal Acquisition Institute, we should all benefit and our concern will vanish.

My remaining comments will relate to our program in three time phases: Past (prior to PSAD-77-128); Transition (the "now" period); and Future (how we plan to conduct our formal program).

Past Phase: We have a long history of independent activities relating to many facets of the acquisition process. The activities have been performed both in-house and by the private sector.

Examples of some areas of prior applied research include:

Source Evaluation and Selection (1964)
Cost Plus Award Fee Contracting (1967)
NASA Acquisition Process (1971)
Support Service Contract Staffing (1976)
Procurement Workload Measurement (1976)

Following are some examples of approaches to research that we have carried on:

Undergraduate work with several universities, including New Mexico State, Stanford, U.C. Davis, and University of Puget Sound:

University Staff Persons (IPA) from Colorado State and University of Washington; and

Through Grants and a Consortium Agreement such as one with the University of Santa Clara to study

- The procurement cycle through simulation
- Workload scheduling
- Employee development procedures, and
- Influences and apparent impact of contract type and structure.

Transition Phase: We are currently involved in several applied research activities which utilize computer technology. The primary programs which have agency-wide impact include workload system development and analysis; common data base regulations; RFP, Purchase Order, and Contract Writing; Sources and Capabilities of A&E Firms and Minority Business Firms; and a special program which "key words" our regulations for ease of reference.

Without any sacrifice to on-going programs, we are also developing a formal organization structure to provide direction and control for our continuing program. We are currently identifying persons within both NASA headquarters and field installations to serve on an acquisition research committee. The committee will include persons from both business and engineering or scientific disciplines. We plan to operate with a chairperson, plus five to seven members.

The committee's primary duties will be to identify all related business research sponsored by NASA and to disseminate its results; maintain liaison with other agencies and the private sector so as to keep current with the efforts of others and to inform them of our results; and to maintain an awareness of the needs within NASA and to use that awareness as guidance toward areas which may be benefited by research. When an area is identified, the committee will develop a research plan. The plan will synopsize the need, identify the most promising investigative group (in-house, other agency, university, or other member(s) of the private sector); establish the funding requirement; identify the period for performance; and recommend the principal investigator who is to manage the program. The plan will be subject to the approval of the NASA Director of Procurement (S. Evans).

Future Phase: We expect to have our committee established and operating within the next two months. Our initial activity will be directed toward explaining what business research is and in developing an agency-wide awareness of its benefits. As we perform this initial activity, we expect to develop a more complete inventory and identify additional research needs. We will then be in a position to establish our research plans and contribute to the interface process outlined previously.

DOE

The DOE representative spoke on the reorganization and restructuring necessary as the agency evolved from the AEC to ERDA to DOE; that the agency's primary purpose was to stimulate new developments in the energy field, and that it had a range of instruments for this purpose, such as:

- o Contracts
- o Grants
- o Cooperative agreements
- o Loans and loan guarantees

Currently, DOE's efforts are directed toward simplifying the above processes and several of the on-going procurement research efforts in these areas were discussed, and are summarized below:

AUTOPREPS

The AUTOPREPS is currently an operational prototype at the Space and Missile Systems Organization (SAMSO) in Los Angeles, for programmed contract writing, and procurement tracking and procurement management information (the last two features are still being developed). Expanded development will include (1) programming DOE procurement regulations on the system; (2) using the AUTOPREPS cathode ray tube terminals as source data entry devices for MIS data flowing to headquarters; (3) direct access to TWX and mailgram networks; (4) communication to large computers containing procurement data banks; and (5) issuance of updated regulatory matter requiring changes in AUTOPREPS-stored text. Two prototype organizations, to be operational by February 1979, are planned. (The FAI is working with DOE, NASA, and the USAF on this project as part of a larger automation project. It will be discussed later in this paper.)

Vendor File

The multipurpose vendor file is expected to serve industrial relations outreach program needs; procurement operations needs; and as an extensive data base edit for our procurement management information systems. Our approach is to build on vendor information existing in our Contracts Information System (CIS) through the mailing of computer-generated letters and attached questionnaires (DOE Vendor Mailing List form), keypunching of questionnaire responses, and editing up to a complete file on existing contractors. New firms desiring to be added to the vendor file will complete the same questionnaire.

Major tasks include the definition of data requirements, development of a new DOE Vendor Mailing List form, and software development. We expect to be able to relate potential vendor capabilities with potential agency needs through use of existing budget and reporting codes, and to be able to relate planned procurements to identified small business, minority business, and labor surplus area business capabilities. The multipurpose vendor file is expected to be available in September 1978.

Improved Procurement Management Indicators

The studv of improved procurement management indicators is estimated to involve up to one man-year of professional contractor effort over a 10-month period, with final implementation and test running through September 1979. We intend to initiate discussions very soon with the Logistics Management Institute, or a similar organization, toward drafting the appropriate agreement. Generally, we believe that procurement management indicators should differ between management levels, with separate indicators at the secretarial, headquarters procurement and technical staff, and buying activity top management levels.

DOE Fee Curve Study

In addition to the foregoing, DOE also has a fee curve study currently being performed by the Logistics Management Institute (LMI). The study objective is to perform a study of DOE declining fee policies and procedures to determine if the present maximum fee curves are realistic and adequate to accomplish their intended purposes.

The remaining agency representatives at the council meeting briefly discussed their agencies' involvement in the procurement and business research area.

General Services Administration

On-going efforts, by in-house staff, include:

- o Buying program improvements
- o Multiple award contract program
- o Benchmark system for evaluation
- o Contract form simplification
- o Test case on tailor-made contract forms
- o Annual money lease/purchase of personal property
- o Marketing Division projects
- o Value Management Division projects
- o ETIP Division and ETIP programs
- o LCC/OFPP charter to GSA

Several other departments (Commerce, HEW, Veterans Administration, Justice, HUD, and Transportation) reported on various on-going study projects which are being accomplished on an in-house basis with their existing staffs.

After the briefings an discussion on the agency programs, Dr. Bennett introduced Captain Ron McDivitt, USN, who heads up the research program at the DSMC and acts as Executive Secretary for the DoD Acquisition Research Council. Dr. Bennett proposed that Captain McDivitt be made a member of the council to provide liaison with DoD procurement/acquisition research activities, and the council concurred.

A proposed charter, prepared by the FAI staff, was then briefly reviewed and discussed. Agency comments on the charter were requested by May 1, 1978, in order that a revised charter could be ready in time for the next council meeting scheduled for June 8, 1978. The proposed charter is reproduced below in order to illustrate the type of organization and functions envisioned for this group.

CHARTER OF THE
FEDERAL ACQUISITION INSTITUTE
CIVIL AGENCY ACQUISITION RESEARCH COUNCIL

I. PURPOSE.

A. The Civil Agency Acquisition Research Council (CAARC) is chartered as a Federal Acquisition Institute (FAI) "Interagency Specialized Work Group" (ISWG), to act as a quasi-operational arm of the FAI in order to plan, communicate, coordinate, and sponsor acquisition research among the civil agency members of the FAI.

B. The CAARC, composed of members from all FAI civil agencies, will report to and advise the Director, FAI, who also serves as chairperson of the council.

II. MISSION. The mission of the CAARC is to:

A. Identify research needs within and across its member agencies and to communicate these needs to the council-at-large and the FAI.

B. Coordinate and sponsor research (1) within a single agency, (2) among several agencies, or (3) trhough the FAI, which will act as a program manager to oversee the initiation, progress, completion, and pilot-testing of research projects as necessary.

C. Develop a plan and/or planning system to accomplish A and B above. This plan or planning system will include a proposed yearly budget for review by the FAI Research Standing Subcommittee and Budget Subcommittee, who will forward a proposed budget to the Director, FAI, to be included as part of the FAI research program budget.

III. COMPOSITION.

A. The CAARC shall consist of members representing all FAI civil agency members and the FAI.

1. These agencies are:

a. Agriculture
b. CSC
c. Commerce
d. DOT
e. EPA
f. GSA
g. HEW
h. HUD

i. Interior
j. Justice
k. Labor
l. NASA
m. NSF
n. SBA
o. State
p. Transportation
q. Treasury
r. VA
s. FAI
t. OFPP
u. DoD (DSMC)

2. The term for a member of the council shall be at the discretion of his agency.

B. The chairperson of the CAARC shall be the Director, FAI. As chairperson, the member will be a nonvoting member of the council.

C. The Assistant Director for Research, FAI, shall be the executive secretary of the council.

D. The vice-chairperson and other positions shall be selected by a simple majority of the council membership.

IV. AGENCY SUPPORT

A. The Director, FAI, provides technical or administrative assistance needed by the council, including WAE part-time employees as deemed necessary.

B. Expenses encountered by council members shall be the responsibility of the parent agencies.

V. DESCRIPTION OF DUTIES

A. The CAARC advises the Director, FAI, on the overall aspects of acquisition research in accordance with its mission.

B. The council responds to requests or assignments from the Director, FAI (as chairperson of the council), and from member agencies.

C. Procedures for presenting the advice, findings, and recommendations of the council should be flexible yet consistent with the group s purpose.

D. The council chairperson shall submit each report or plan through the Research Standing Subcommittee and Budget Committee to the IWC.

The number and frequency of the meetings will be determined by the council; however, during the organizational phase, quarterly meetings are being scheduled.

The charter, after agency inputs, will be approved by the council, the FAI IWC, and Dr. Bennett as the Director, FAI.

Since the Civil Agency Acquisition Research Council will act primarily as a communication and coordinating body, it will be up to the FAI to provide overall thrust and momentum for specific research projects. Two on-going projects will serve to demonstrate the coordination role that the FAI will play in relation to the council.

One of the first FAI research projects to demonstrate the benefits of overall FAI research management occurred during its first month of operation in September 1977. Prior to the operational phase of the FAI, the OFPP had completed a Federal Government-wide survey of "cost estimating" techniques employed by the various agencies and, after the formation of the FAI, OFPP requested that it manage a contract study effort in this area. During a review of other proposed research projects, it was discovered that the APRO was about to undertake a similar in-house Army study on cost estimating techniques. Discussions were then held with the Logistics Management Institute (LMI), the support contractor for the OFPP study, and with Dr. Paul Arvis, Director, APRO. As a result, instead of two isolated studies, both efforts were joined into one project benefiting from the combined funding of OFPP and APRO. The study and agencies to be visited were divided between LMI and APRO, with APRO as the project manager, responsible for preparation of the final report with input from LMI. FAI is acting as the overall manager of the study for the OFPP, and the project has benefited from the synergistic effect of combined funding and the merging of two similar projects into a larger and more comprehensive effort.

The "Automation" ISWG being formed by the FAI is another project that is setting a pattern for future efforts. It evolved from the three DOE automation projects previously discussed (i.e., AUTOPREPS, vendor file, and improved management indicators). The DOE, in February 1978, set up a cooperative effort with NASA and the Air Force to install and pilot-test these projects. Upon learning of them, the FAI asked the DOE to take a lead agency role and chair an "Automation" ISWG, which was accepted by DOE in a letter to Dr. Bennett dated April 7, 1978. Under this arrangement, the ISWG will oversee the pilot test and, through a part-time employee supplied by the FAI, conduct a government-wide survey on automation currently employed in the procurement and acquisition process. The ISWG reports on these efforts will then be furnished to all FAI member agencies, who can use this information to assist them in their own automation projects. The CAARC was very receptive to this project since several member agencies were planning to

develop or look into automation of their processes.

Civil Agency User Needs Study

The FAI is also planning a direct program of support to the civil agencies by undertaking a one-year user needs study. Dr. Richard Lorette, as of April 17, is on an intergovernmental transfer from the University of Southern California for a period of one year and will have as his primary responsibility the accomplishment of this study.

Using the members of the CAARC as starting points, Dr. Lorette will visit each agency to discuss their procurement and acquisition problems. This effort will include recommendations for an overall planning system, which will include a framework of contract administration research needs/projects and a basis for assigning priorities, allocations, and resources to do the research work.

There are also several on-going and proposed FAI research projects on developing the "tools of research" that will be of benefit to the procurement community, in general, and will be of particular value in working with the civil agencies. Among these tools of research projects are the following:

Federal Research Cataloging System

This project has been undertaken for the FAI by the Army Procurement Research Office under the direction of Dr. Paul Arvis. The initial effort of this project will be to update and expand two guides that the APRO prepares for DoD use on a government-wide basis. These two documents are: (1) "A Guide to Source of Information for Procurement Research," and (2) "Resources for Performing Procurement Research." The expansion and consolidation of these documents will be of obvious benefit to the operational user and researcher in the civil agencies by providing them with information on research resources and existing information centers, data banks, and published materials.

Procurement/Acquisition Research Policy and Planning Guide

This project is also a jointly sponsored effort undertaken for the FAI by LTC Daniel Strayer, Executive Director of the Air Force Business Research Management Center. The purpose of this program is to prepare a guide which defines procurement and business research, sets forth Federal roles and responsibilities, outlines various research processes, identifies research methods, and will provide other guidelines for accomplishing procurement/acquisition and business research. The need for this guide has become readily apparent when discussing procurement research with many of the civil agency representatives who have several interpretations, some misleading, of the term "procurement research." The guide will build on several long-range projects that have been in progress for several years between the AFBRMC and the Air Force Institute of Technology. These concerted efforts have resulted in several excellent papers and two student theses efforts in defining procurement research (7:90-99), construction of sequential research needs (3:2-4), and a taxonomy of research for procurement (4:51).

On a day-to-day basis, the guide can be used to provide a basis of communication between user and researcher to define the need or problem and to ascertain the level of effort necessary to study and/or research the area. One important aspect that the guide will illustrate is that a formal organization is not a prerequisite to accomplishing procurement research since the levels of effort can range from a one-man staff study to ad hoc groups, a master's thesis, contract research, to a doctoral dissertation (8:27). This type of information will be particularly valuable in stressing the user need aspect of procurement research and the need for collecting many agency in-house or contracted procurement or business research efforts.

The FAI Library

Another valuable FAI tool of research is the FAI library. The library is unique in that its collection focuses on procurement books, periodicals, research works, and unpublished papers generally not found in other libraries. As the FAI and civil agency programs evolve, the library's materials and services will play an increasingly valuable role as an information center, clearinghouse, and reference service for both users and researchers.

University Research Consortium

The FAI is also planning to sponsor a university research consortium project. In its first phase, a consortium would focus on textbook and faculty development, then evolve to a program of university research. Currently, the FAI has three activities in this area underway: tracking a Georgetown University study on Federal management research sponsored by the Civil Service Commission, working with American University to get HUD grants assistance for joint American University/FAI degree programs, and assisting Harvard University to obtain a National Institute of Education grant to form the lead consortium effort. One of the primary long-range goals of this program will be to provide a source of procurement/acquisition and assistance research for the civil agencies.

Future Programs

As the efforts of the FAI and the CAARC evolve, we can expect more joint agency research projects and programs. In the two civil agency

council meetings thus far, there has already been a strong indication of a commonality of problems and needs and a willingness to communicate and/or cooperate on various on-going and proposed research efforts. In order to work toward the goals discussed in this paper, the FAI will support the CAARC with a user needs survey and develop recommendations for a planning system. These efforts will take into account the personnel shortage that precludes formal research organization and will concentrate on developing a program that will make maximum use of existing in-house capabilities, contracting out efforts to assist management in the procurement/acquisition research area, and the use of the proposed university consortium.

During the next several years, as we move toward a single government-wide acquisition statute and acquisition regulation, the commonality of problems and research needs will serve to bring all Federal agencies, civil and DoD, into a closer need for cooperation and jointly sponsored research programs that may eventually be merged into one Federal acquisition research planning system.

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DEVELOPING A PROCUREMENT EXPERIMENTATION SYSTEM

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ABSTRACT

To discuss the use of administrative experimentation in testing changes in acquisition and procurement procedures and policy. This panel will serve as a forum for describing past and current experiments as well as for identifying opportunities for new experiments.

INTRODUCTION

Government procurement agencies and units are faced with a number of continuing issues. They include, but are not restricted to, the following:

- What products or services should we buy?
- How should we buy those products or services?
- How should those products or services be stored, delivered, etc.?
- How can I make an award to the best bidder?
- How can I effectively spend our budget?

Because of changing user requirements, changing technologies, changing market structures and the like, these issues must be regularly revisited.

The Experimental Technology Incentives Program, National Bureau of Standards is interested in how government agencies answer these questions. In particular, ETIP examines how the answers adopted by government agencies impact the commercial sector. ETIP attempts to identify those answers or solutions to the above questions which seem to act as incentives for technological change in the private sector [1].

ETIP carries out this examination by working with other government procurement agencies and departments in order to test changes in procurement policies and practices [2]. These tests, it believes, will provide answers to the above questions. However, as markets users and technologies change, periodically new answers and solutions have to be tested.

In order to most efficiently conduct such periodic testing of procurement methods with other agencies, ETIP is developing what it terms "procurement experimentation systems" [3]. Such a system specifies in great detail procedures for defining procurement issues, for collecting background data in agencies and industry, for designing tests of specific changes in procurement policies and practices, and for analyzing the effects of such changes on the agencies themselves and on the private sector [3]. What follows is a brief description of one approach used by ETIP to develop such a system.

WHAT IS A PROCUREMENT EXPERIMENTATION SYSTEM?

A procurement experimentation system can best be described by outlining the kinds of services it can provide to potential government and industry users. These services are broken down into four categories:

- Identifying opportunities for procurement tests or changes for government agencies.
- Determining the feasibility of such tests.
- Designing the tests.
- Assessing the effect of the tests on the agencies conducting them and the industries affected [4].

IDENTIFYING OPPORTUNITIES

An opportunity for a procurement test or experiment exists when individuals within a government agency attempt to resolve one of the five issues outlined at the beginning of this paper and when they are interested in carefully testing potential solutions. The "identification procedures" of the system can collect data to help them determine:

- What new products or services they ought to be buying?
- What old products or services they ought to stop buying?
- What products or services might better be bought in a different way?
- Etc.

Such identification procedures can be used to identify newly emerging technologies in the private sector which might be acquired. They also can identify products for which purchase volume has decreased—indicating perhaps, a shift in user requirements.

If after receiving the results of the identification services individuals within procurement agencies wish to contemplate some procurement change, they can elect to obtain a feasibility analysis.

PROCUREMENT EXPERIMENT FEASIBILITY

The feasibility analysis can be described in six stages:

- Determining how a particular agency and selected industry operates.
- Determining information needs and rigor requirements of procurement officials making the test (and other interested parties).
- Determining what procurement changes are feasible.
- Determining what test strategies are feasible.
- Determining what data can be collected and what likely impacts will occur in the agency and the industry.
- Based on the above, determine what information needs and rigor requirements can potentially be satisfied by the experiment.

A major objective of a procurement experimentation system is to support the information needs of individuals making procurement changes. Hence, it is important to carefully determine what these needs are. Does the procuring official wish to determine industry attitudes towards his operation? Does he wish to determine the cost of the procurement method tested? Does he require a controlled test, or would a "quick and dirty" study suffice?

The next step in this analysis is determining what procurement methods can feasibly be tested. Resource, legal, and organizational constraints must be considered--for example, if a new method requires special testing facilities which are not available, then the method is not feasible.

Once ETIP has determined what is needed and what is feasible, it examines to determine if an intersecting of these two sets exist. Only that data analysis and findings which both will satisfy interested parties and can feasibly be provided become the focus of the procurement test. They become the focus of the design stage which follows.

DESIGN PROCEDURES

During the design stage the cooperating procurement agency and ETIP specify in detail:

- How the procurement change is to be implemented in order to provide for the required level of rigor.
- What potential interfering factors are to be controlled for or accounted for.
- What data is to be collected.
- How the data is to be collected, stored, analyzed and processed.
- The precise nature of the anticipated findings, how they are to be used and by whom.
- Who is to collect the data (Agency, ETIP, or Industry).
- Schedule of events--both procurement and data collection and analysis.
- Budget.

In short, the design process describes in great detail the tasks to be carried out during the test of the selected procurement change.

ASSESSING THE EFFECTS

Three kinds of effects are of interest in a procurement experiment:

- The effect of the change on the agency.
- The effect of the change on industry.
- The effect of the feedback provided by the procurement experiment on agency decision-making, strategies and procedures.

ETIP or a contractor observe how the change is implemented in an agency, how the agency is perceived by industry and any changes that occur in either place. Ideally, this process of observing the change begins prior to the change itself. This enables the collection of base-line data. Such data, in addition, permit mid-course corrections as the procurement is being implemented.

SYSTEM DEVELOPMENT

To be more effective in the conduct of its procurement experiments, using the process described above, ETIP has concluded that a systematic approach is required [3]. Such systems are not typical objectives of federal government policy research programs [5]. In most cases, a policy research program asks a contractor to conduct a particular study or evaluation. In ETIP's case it is asking a contractor to conduct specific studies and evaluations, but also to document how these tasks are carried out.

This documentation will enable ETIP to carry out some of these tasks in-house. It will also enable ETIP to operate more effectively in the following ways [6]:

- Faster response time for initiating new experiments.
- Increased ability to draw comparison across sets of experiments because of comparable methods used.
- Reduced cost of evaluation because designs do not have to be developed anew each time.
- Increased certainty in predicting time cost and personnel requirements of a particular experiment.
- Easier to communicate with agencies and industry what is involved in a procurement experiment and what they can get out of it because an explicit set of procedures exists as well as an associated set of sample reports and products.
- The ability to purchase information in well-defined segments before committing to full-scale experimentation.

To carry out system development, ETIP with the assistance of private contractors works through 10 steps.

Step 1. Decide who the clients of the system are to be. For ETIP and for the ETIP procurement area these clients would be individuals making changes in procurement practices or procurement policies within procurement agencies, within procurement departments or within OMB or the Congress.

Step 2. Decide or determine what the information needs or variables of concern of these clients are.

Step 3. Identify existing data banks in the agencies in the private sector which collect data in a way that would satisfy clients' information needs. Specify the procedures for accessing, collecting together, analyzing, and reporting this data.

Step 4. For those information needs for which appropriate data banks do not exist, identify and locate existing data collection and analysis procedures, research designs and the associated products they were used to develop that could be used to satisfy the residual set of information needs. These data collection and analysis procedures and research designs are located within organizations who have conducted research on the same or related information needs and have produced products that were used to satisfy information needs. These sample reports on products can be used to confirm the extent to which the clients would be satisfied if they received a product similar to it.

Step 5. Develop research designs and data collection and analysis procedures for those information needs or variables not covered by existing data banks or existing designs and procedures.

Step 6. Adopt and/or develop input, output, processing and storage procedures as needed to satisfy the basic clients and information needs.

Step 7. Get the agencies or other relevant parties to augment their existing data banks to collect the data that is needed but is not being collected already.

Step 8. Assemble the system.

Step 9. Test the system in the context of some specific experiment.

Step 10. Document system.

To carry out these steps ETIP, its contractors, and the cooperating agencies must first identify, based on their background data collection, who the clients of the system are to be. This is a list agreed upon with ETIP and it serves as the focus for the remaining tasks.

Once the clients have been identified, their specific information needs have to be determined. What do they need to know in order to alter either a procurement policy or practice that they have control over? ETIP does not always have to do specific experiments in order to determine this. Instead, ETIP can simply present them with facsimiles of actual products produced by the existing data banks to determine if feedback of that sort would enable them to make decisions about changes in procurement practices and policies.

Next ETIP, other agencies and/or contractors identify the set of data banks or data collection and analysis systems already in existence within government agencies and the private sector collecting data either clearly or potentially of interest to this set of clients. The nature of these data banks, what they produce, the instruments they use, how the data is stored, etc., should be compiled. This is further background information. In addition, the sample products that these information systems produce should also be on file. This inventory of data banks and what is produced by them, how it's produced, is the first piece of the evaluation system.

If the data banks do not suffice, then other kinds of research designs and data collection

and analysis procedures have to be identified. ETIP then looks for other studies, experiments that have been done by other organizations and contractors which have produced reports relevant to the information needs not covered by existing data banks. The sample reports, the data collection procedures, data analysis procedures and research designs used to produce those reports should be brought together and put on file and their appropriateness tested by presentation to the specific clients. In other words, if a procurement official needs a certain kind of variable measured and an existing data bank within FSS or within DOC or the private sector does not provide that information, then a report which has been provided in the past by e.g., NSF or some other group has to be presented to the interested procurement official. If he likes the report, then the procedures used to develop that report will be used in an experiment that he is conducting at sometime in the future.

Now, if neither a data bank nor an existing data collection analysis procedure exists, then ETIP or its contractors will have to develop the procedure. In most cases, it is likely that many of the clients' information needs can be satisfied by some existing or some modification of some existing study, report, or procedure used to develop those reports.

In sum, once the clients have been identified, their information needs determined, and the combination of existing data banks and existing data collection and analysis procedures that would satisfy those information needs have been brought together, and once all redesigns or new design efforts are completed, we'll then have what ETIP calls a prototype system. ETIP then has to test the system on an experiment with one or more of these clients. Procedures will be picked out of this filing cabinet and used to conduct that experiment.

The next phase in system development is the test phase. The set of procedures developed must first be tested by individuals other than the original developers. ETIP is having contractors form a new group which can operate and test the system apart from the original developers. Eventually, ETIP would like to test the system in a government agency.

These two tests ensure that contractors will leave with ETIP and other interested agencies a capability for systematically carrying out and describing the effects of procurement changes on industry.

SUMMARY

ETIP has concluded that the effective conduct of procurement experiments requires a systematic approach. A brief description of a procurement experimentation and a ten-step process for developing one has been presented.

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HYPOTHESIS AND CLUSTERS IN NAVY'S ACQUISITION RESEARCH

(A contribution toward the problem of research methodology)[1/]

Dr. F. A. P. Frisch[2/]

FOREWORD

The present paper tries to address problems inherent in the development of a coherent plan for research acquisition. The problems are epistemological and similar in nature to problems of all those sciences which are based on an axiomatic or philosophical foundation where right and wrong are determined by the acceptance of some initial propositions and where no quantitative solution is possible on solely objective basis. This of course does not preclude that specific research topics are exclusive quantitative problems. However, even the solution of all quantitative problems - if such were possible - could not solve the puzzle of acquisition. Furthermore, there are too many measurable problems to ever be solved. Therefore, one has to start with a goal and go from the goal backward toward those problems which selectively support the goal and neglect all other topics. The goals do not have to be too esoteric and some are suggested in the form of a research hypothesis.

The paper itself does not intend to present a finalized research plan. It only shows how such research plans can be developed and how relative consistency of research topics can be achieved.

I. TOWARD A PHILOSOPHY IN ACQUISITION RESEARCH

We scientists have brainwashed our less scientific contemporaries into an unshakable belief in the power of our wisdom and the power of research: that nothing is beyond solution if we have just enough money and manpower to research it up and down. We have given up the naive notion about the apocalyptic riders as God-sent punishment which we have to endure in humility. In short, we got awfully arrogant. This arrogance may be halfway justified as long as we devote ourselves to the so-called hard sciences where we can measure and weigh the inputs and outputs of our research. The justification for arrogance, however, evaporates as soon as we shift our endeavor to what we like to call in colloquial terms the soft sciences; acquisition research is at least in part such a point in case.

Let's think about it this way; the process of acquisition takes place in a legal (political) environment, deals dominantly with products of engineering and is evaluated in terms of economy. Hence, acquisition research must be an interdisciplinary activity which I like to describe with my pet acronym as a subject of LEGENOMY, meaning the ubiquitous interaction of lex-al and en-gineering aspects with elements of econ-omy. Two of those disciplines - law and economy - belong in the domain of soft science, where everything is right as long as it is consistent with the underlying axioms and by definition wrong if it contradicts our weltanschauung.

I would like to rephrase the last sentence and say that law (also encompassing politics) and economy are DECISION SCIENCES (and not MEASUREMENT SCIENCES like engineering). A decision science shall be defined as any science where the process and/or the result of research has no unique solution without accepting a priori a subjective decision process based upon subjective axiomatics or philosophy or value judgement. Specifically, any acquisition process takes place in the penumbra between decision and measurement sciences - and here lies the problem and the inherent contradiction for the planner of

1/ This paper represents the personal opinion of the author and does not necessarily reflect any official opinion of the Navy or any other department or government agency or the opinions of the author's present and past associates.

2/ Department of the Navy, Naval Sea Systems Command Code OOXC, Washington, D.C. 20362

acquisition research: how to develop a logical research plan which gives objective answers to subjective problems? How can we learn to live with this epistomological impossibility and still produce a useful result, where useful is defined in plebean terms as any knowledge which gives us a bigger bang for our buck?

This is the problem of acquisition research in a nutsnell. We have agreed we need it, we have agreed that we should do better and more in our acquisition research. But this is also the end of our concensus. Just look at the different contributions to acquisition research made over the last few years: everything is represented from contributions in graph theory barely understandable to a few fellow-mathematicians up to incentive labor studies made by our friends in the social science departments. No question, all of those contributions are related somehow to acquisition. However, they are disjoined. We cannot recognize how they hang together, what the practical value of each contribution is and how the different contributions can be utilized. Such uncertainties and disjoined research activities do not exist for example, in the research plan for the moon project. Here it is so easy to develop the research plan for a missile which should go to the moon. Accepted, it is a very difficult and immensely complicated task, but there is nothing complex about it because only one single objective exists; namely, to shoot a missile with a desired payload from point A to point B. The only philosophical and hence true decision to be made is "to do it" - everything else is then a fill-in job. But to go to the moon is not only a single (and therfore, not complex) objective, it is also a non-ambiguous objective. The pursuance of this single objective tells us then what the holes in our knowledge are and hence gives us specific research topics. We may discover we need a more powerful booster or a more responsive guidance system and so forth, down to the last detail until the mosaic is completed. But, maybe even more important, we also know what is NOT our problem. In short, this research is bounded by clear and well defined goals and we can lay out the research tasks and subtasks with great precision. Furthermore, all those tasks are within the measurement sciences, where calculation, experimentation and testing deliver non-ambiguous measureables and invariable repetitive results; the pros and cons of all decisions are quantifiable with exactitude, and opinions can be substituted by knowledge - in essence, we have to make choices between alternative solutions but not decisions (against uncertainties).

Let's contrast to this the problem of acquisition research. In acquisition research, we have only vague goals - and not only this, we have many and often divergent goals. This makes the subject complex although the individual tasks may be relatively simple. We do not even know what our problem is NOT. Should we concentrate on acquisition strategy or on improved management control? Do we need an improved management control if we would have a better acquisition strategy? What do we mean with improved management control and acquisition strategy? These are all very good sounding statements of noble goals, like being for motherhood and against sin. But each of those statements highlights that the subject of acquisition research is unbounded by a specific goal; at best, it is framed with good intentions, like the way to hell and most other subjects belonging in the group of decision sciences. In turn, this does not permit us to lay out research tasks or subtasks with any resemblence to precision and defined interaction.

This is the dilemma we face in planning of acquisition research. How to get out of it? How can we remove the complexity (multiple goals) of acquisition research and bring it down to the un-complexity (single goal) of the moon missile? How can we organize the structure of research tasks with the same clarity as the task structure of the measurement sciences? Can it be done?

It is possible; but it is only possible if we can define substitute goals in acquisition research. A substitute goal is the postulation of a nonambiguous and singleminded result - like shooting a missile to the moon - which we will pursue and bring into reality. Then we will go behind the goal and turn all stones which are in the way to reach this goal - but no others. Such substitute goals will let us handle subjects of decision sciences like subjects of measurement sciences: the determination and singlemindedness must be postulated in the form of a research hypothesis. The research hypothesis is our ersatz missile for the moon shot toward better acquisition and the search for how to build the ersatz missile (substitute missile) will lead us with the highest possible precision toward research topics (alias holes in our knowledge related to acquisition).

To make myself better understood, I offer you my most favored substitute goal for Navy related acquisition research: "We will do everything in order to form an economically viable U.S. shipbuilding industry second to none and solely based upon private commercial demand; in turn, all our Navy needs will be satisfied by a strong industrial base whose health is not the Navy's concern." Now we can look for the booster of our ersatz missile and for the guidance system we need to shoot to our ship-building-oriented moon.

For those of you who desire to call me a fool and for those of you who desire to agree with Barbara Ward and Peter Drucker, stating that shipbuilding and some other old and over-matured trades are an anachronism in an economy of mass production and a consumer society, and hence must and will be shifted into developing countries - for all those I offer you a different substitute goal to tackle acquisition research: "The U.S. shipyard industry has no justifiable economic basis in the commercial world and hence, if needed for political/military reasons, will be the sole responsibility of the U S Navy, and therefore, the Navy must do everything to maintain the industrial base for shipbuilding " Ferguson and his editor [illegible] Jantscher may enjoy this ersatz mis[illegible]

The two above substitute goals, first the institution of a healthy and Navy-independent U S. shipbuilding industry and second, the institution of a solely Navy-dependent U S. shipbuilding industry are unquestionably extremes. It is a painting in white and black which may only exist in dreams. Reality will be somewhere in between and may offer itself in unlimited shades of gray, elusive to exact definition. In reality, we have to work in gray and plan in gray - however, we cannot think in gray because gray is no definable concept; only black and white is. Also, even though white and black may be at the end of the probability spectrum - or even outside of the spectrum, their existance, or better, possibility of existance cannot be denied. Black and white can also be called the thesis and the antithesis and the gray area in between the synthesis. Hence, I suggest that acquisition research start with a set of substitute goals in the form of non-ambiguous research hypotheses described in the form of thesis (pro) and antithesis (con) and searches for the synthesis. Otherwise we will never arrive at a coherent and interacting research plan of acquisition topics. We must be willing to accept a set of research goals and associated research methodologies which permit us to treat the problems of acquisition research (which in itself is a decision science) simil[illegible]y to problems of the measurement science We have to substitute the fairy tale of scientific neutrality with a set of essentially subjective political/military/economic goals which we can dress up in the form of a boundary hypothesis subject to prove or disprove. Only in this way - or with this methodology - are we able to handle the amorphous and unbounded area of acquisition. Initially, the extreme hypotheses or boundary hypotheses are postulated perceptions embracing the zone of reality. We must have the courage to express a possible, although often highly improbable vision of how we would like to see our goals before we are able to fill in research tasks with scientific neutrality in order to complete the picture and close the loop from the border hypotheses toward the synthesis or reality.

2. A SET OF BOUNDARY HYPOTHESES

I am using the term hypotheses quite liberally in order to describe a goal, a concept, a possibility or an opinion on a particular subject. Accordingly, I define a boundary hypothesis as an extreme of such goal, concept, possibility or opinion, being well aware of the black and white painting. I consider the boundary hypotheses as a research tool which forces us to recognize needed knowledge and hence research topics as necessary to defend the hypothesis. This in turn will lead to a coherent body of knowledge to deal with the wide spectrum of acquisition.

At this moment I offer six hypotheses for discussion. I will start with very general subjects and proceed toward specific Navy related subjects. A justification will be given only for the last hypothesis. In my opinion, the six hypotheses are sufficient to cover the entire acquisition spectrum

HYPOTHESIS #1 ON THE UNIFORMITY OF PROBLEMS

- PRO: All procurement problems are the same and independent of the procured goods. Therefore, all procurement processes can be handled identically.

- CON: Every procurement problem is an individual problem, depending upon the specific product, the specific producer and the specific economic condition of the procurement time.

HYPOTHESIS #2 ON THE RELATIONSHIP BETWEEN INDUSTRIES

- PRO: A strong commercial industry is the necessary backbone for a strong military industry.

- CON: The capability of the commercial industry and the capability of the military industry are not related to each other.

HYPOTHESIS #3 ON THE UNIFORMITY OF MANUFACTURING

- PRO: Manufacturing metho[illegible] commercial goods and manufacturing methods for military goods are identical

- CON: Manufacturing methods for commercial goods are not compatible with those for military goods.

<u>HYPOTHESIS #4</u> ON THE RELATIONSHIP BETWEEN PRODUCTION VERSUS CONSTRUCTION

- PRO: All manufactured goods are the result of a production process whereby a production process is defined as an operation which manufactures an unlimited number of identical pieces.

- CON: All manufactured goods are the result of a construction process whereby a construction process is defined as an operation which manufactures one of one individual piece with unique and not repetitive characteristics.

<u>HYPOTHESIS #5</u> ON THE NATURE OF SHIPBUILDING

- PRO: A shipyard is a place where a ship can be launched and assembled from parts and building blocks which are manufactured outside of the shipyard. (Assembly yard)

- CON: A shipyard is a place where a ship can be launched and assembled from parts and building blocks which are all manufactured in the shipyard. (Fully integrated yard)

<u>HYPOTHESIS #6</u> ON THE VIABILITY OF THE SHIPBUILDING BASE

- PRO: <u>The commercial hypothesis</u> on shipbuilding postulates: A commercially viable shipbuilding industry is possible in the U.S.A. because of (a) the industries' competitiveness on the world market and (b) a strong and commercially viable U.S. ocean transportation industry. Therefore, the Navy does not have to be concerned with the health of the industrial base for shipbuilding.

- CON: <u>The military hypothesis</u> on shipbuilding postulates: The industrial base for shipbuilding in the U.S.A. can only be secured through Navy contracts and therefore, the Navy must be concerned with the health of this industrial segment.

2.1 <u>Justification for the Hypothesis of the Viability of the Shipbuilding base (Hypothesis #6)</u>

I have stated before that a research hypothesis may well be an extreme statement, but nevertheless, the hypothesis must have some root of credibility. Since I consider the Hypothesis #6 as the most important one for the Navy - but also as the most disputed - I have selected this hypothesis to develop an <u>illustrative</u> defense. This, however, shall <u>not imply</u> that within the total scope of DOD acquisition, the other five hypotheses are of lesser importance.

In trying to justify the commercial and the military hypotheses, I would first of all like to reverse the order and start with the military hypothesis.

The <u>military hypothesis</u> is close to present public opinion and has its intellectual foundation in the 1961 study of Northwestern University with the title, "The Economic Value of the American Merchant Marine" by Ferguson et al. (An editorialized version was published in 1975 by Jantscher of the Brookings Institute under the title, "Bread Upon the Waters.") While Ferguson's study had some justification by the tremendous economic superiority of the U.S. in 1961, Jantscher's rehash is utterly out of place. Ferguson's and Jantscher's doctrine is most simple: "We (the U.S.A.) do not need a merchant fleet because we can buy the service cheaper from others."

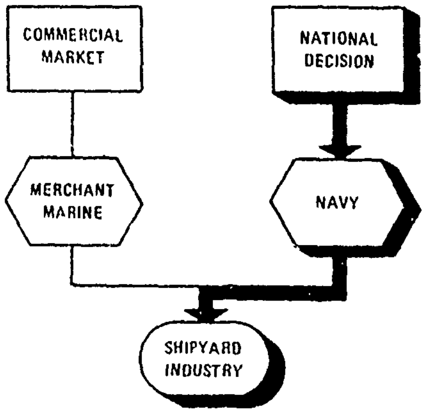
The mental acceptance of the Ferguson doctrine induced sufficient powers to stay away from any serious consideration of a U.S. Merchant Marine and led in turn to its systematic decline. I do not want to go into an analysis of Ferguson or Jantscher despite the fact that I consider both essentially substantively wrong. The military hypothesis, a direct outgrowth of Ferguson's doctrine, is depicted in Figure 1.

The shipyard industry essentially depends upon the Navy, and whatever the Navy has to do depends upon national decisions with regard to defense goals. The consequences of the military hypothesis with regard to cost of Navy ships should be quite clear: extreme expenses and the entire burden of maintaining an effective industrial shipbuilding base resting with the Navy.

I personally do not subscribe to the military hypothesis; however, I also cannot deny the possibility of its realization.

As defense for Ferguson (but not for his later copyist Jantscher) it can be said: in 1960 when the study was made, the U.S.A. (1) dominated the world economy and the dollar

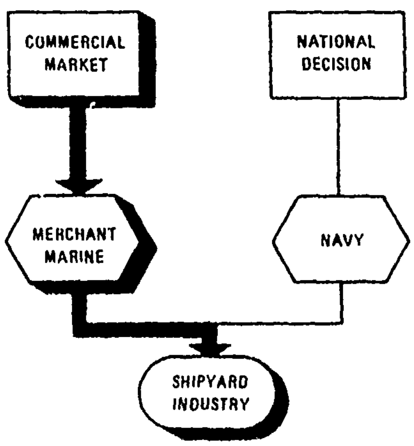
FIGURE 1: MILITARY HYPOTHESIS



was THE currency; (2) military superiority was taken for granted and (3) military expenses were accepted as a national necessity. Under such favorable conditions, Ferguson might have been not completely wrong by saying "nah so what?" about a U.S. Merchant Marine.

The commercial hypothesis which I have postulated takes care of the realities of 1978 and presumably the next decades: (1) the dollar has weakened and the balance of payment deteriorated; (2) American wages have reached parity with many other shipbuilding nations; (3) military expenses are subject to utmost scrutiny and (4) unemployment develops toward a national problem. These are four conditions which are quite opposite to those in 1960, and therefore it may well be that the justification exists to promote - and also the probability of creating a healthy U.S. Merchant Marine, and in turn, an effective shipbuilding industry. The picture which I think is realistic is shown in Figure 2.

FIGURE 2: COMMERCIAL HYPOTHESIS



In my judgment, in 1985 by the latest, the U.S.A. could have a most healthy U.S. flag Merchant Marine and a shipbuilding industry fully competitive on the world market. In turn the Navy could be completely free from any burden of maintaining the industrial base for shipbuilding, and healthy shipyards could compete in the best traditional way of free enterprise for Navy orders.

Since wage parity with most of our competitors is already established and the American technical know-how to build ships is hardly inferior to the others, the question comes down to a legal-economical point which is essentially embedded in political thinking: are we willing or not to provide to the U.S Merchant Marine complex (shipping companies and shipyards) operational parity to our foreign competitors? (I am talking about operational parity and not operation subsidy.) The operational parity would have to consist of (1) tax parity, (2) design parity and (3) route parity. The tax parity would establish for any American built ship and any ship flying the American flag parity in taxation with flags of convenience. The design parity would accept the international safety rules for American built and U.S. flag operated ships in the same way as applicable to ships with flags of convenience. The design parity would also include manning requirements. The route parity would give American built ships with the American flag in the liner trade the same operational freedom as enjoyed by other flagships. Also, parity to participate in internationally accepted rate practices should be included as well as fifth freedom operations.

A recent study of the first National Bank of Chicago points toward the importance of tax parity and the so-called Celler Hearing, Antitrust Subcommittee No. 5 of 1961 informs us about problems related to design and route parity. An economic impact analysis of the Merchant Marine Act of 1938 and its amendments and successors, as well as of the background to the Merchant Marine Sales Act of 1945 would be enlightening.

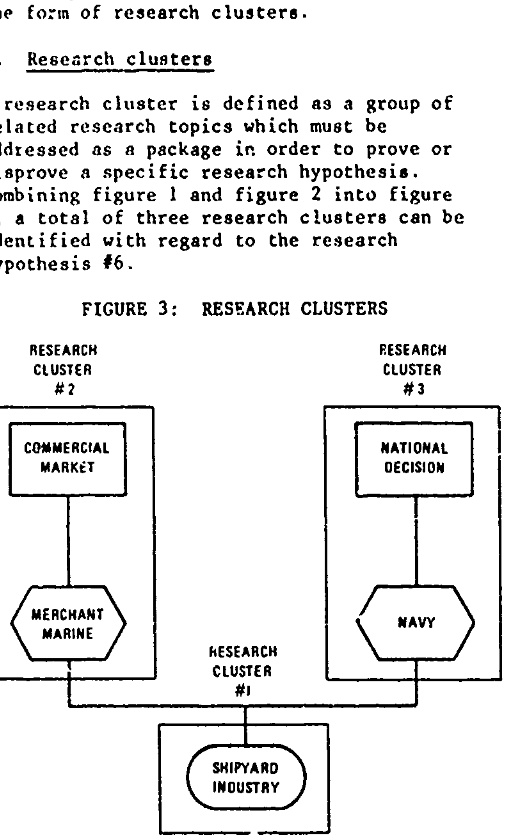
If operational parity could be established, maybe 100 or 200 major ship orders per year - or about 2 or 4 billion dollars - could go into the American economy instead of foreign shipyards. Not asking for taxes on future business which we do not have now is no loss; altogether, the U.S. would gain. The economy of the commercial hypothesis is not difficult to prove - of course, more study is needed. However, the problem is political: are we willing to make separate laws for the Ocean Industry as other countries do? Maybe a prospectus of a "future balance sheet" would be convincing. Quite some homework has to be done in order to arrive at this "future balance sheet". We call it research. What

do we really know of drafting the balance sheet? What do we have to know? The necessary work to be done is indicated in the form of research clusters.

3. Research clusters

A research cluster is defined as a group of related research topics which must be addressed as a package in order to prove or disprove a specific research hypothesis. Combining figure 1 and figure 2 into figure 3, a total of three research clusters can be identified with regard to the research hypothesis #6.

FIGURE 3: RESEARCH CLUSTERS



Suggested topics for the three research clusters are listed below together with a syllabus for each topic. For the purpose of this presentation, only a few of the most important topics are listed; it is only an illustration of how research clusters can be developed.

Topics for Research Cluster #1

- Foreign Management Systems on Shipyards in Order to Learn If, How and Why Foreign Shipyards are Supposedly so Superior to U.S. Shipyards
- Decentralization of Shipyards by Major Trades and Investigation if Some of Those Trades Could Operate as an Independent Business
- Technology Utilization in Order to Determine Practical Limits of Facilitation
- Optimum Range of Subcontractors in Order to Develop a Full Set of Criteria for a Make and Buy Decision
- Principles of Planning as Function of Shipyard Facilities and Ship Type
- Planning Model, Incorporating Facilities, Resources and Budget
- Optimal Size of Shipyards
- Variable Workload, Work Density and Output
- Labor Taxonomy and Availability

Topics for Research Cluster #2

- Legal Environment of Shipbuilding. Determine the national and international laws influencing and controlling ocean transportation
- Economy of Shipbuilding. Determine the elements which influence the economy of the entire ocean transportation and shipbuilding industry.
- Substitute for the Market. Determine the degree to which contractual arrangements can substitute for the market.
- True and False Competition. Determine the conditions necessary for a healthy industrial competition and the degree to which competitive aspects can be fostered by regulatory involvement.

Topics for Research Cluster #3

- Implementation Mechanics. Determine the necessary legal framework which permits the most efficient management of the industry.
- Data and Retrieval Management. Determine the data and the boundary for micromanagement for government guidance to the industry.
- Lifetime of Navy Ships; Time/Quality Cost. Tradeoff between lifetime of ships and initial quality.

Mixed Topics, Belonging to More than One Research Cluster

- Research Need. List perceived research need and separate perception into symptoms and real causes.
- Problem Logic. Develop guidelines which permit the determination of the solvability of a given problem.
- Commonality between Civilian and Defense Industry

- Management Form and Product Form. Investigate the relationship between the manufacturing process of a product and the most appropriate management form.

- Capital Investments, Utilization, Depreciation, Cash Flow

- Risk and Profit in Construction. Determine the spectrum of risk and risk sharing between customer and contractor in shipbuilding.

- Forecasting; Retrospective/Economic/Market. Determine the historical validity of forecasts and develop a method able to indicate forecast quality.

- Commercial versus Military Product Usability

- Piece/Time Wages

NO CLAIM IS MADE THAT ABOVE GROUPING FIRST, IS COMPLETE, AND SECOND, PRESENTS THE ONLY POSSIBLE GROUPING.

3.1 Organization of Research Topics

The research topics, identified within the three research clusters, will be the domain of different disciplines most competent to deal with the problems and hence will be a part of a specific research group. For illustrative purposes, I have identified eight such research groups as follows:

(1) General

Topics in this group are of general interest and independent from the hypothesis where applied.

(2) Management

Topics in these groups are considered essentially problems of management; also they may quite frequently infringe on engineering, law, economy or other groups.

(3) Legal

Topics in this group are considered essentially as legal problems, despite the fact that these topics may have strong economical traits and may also influence to a lesser extent other groups.

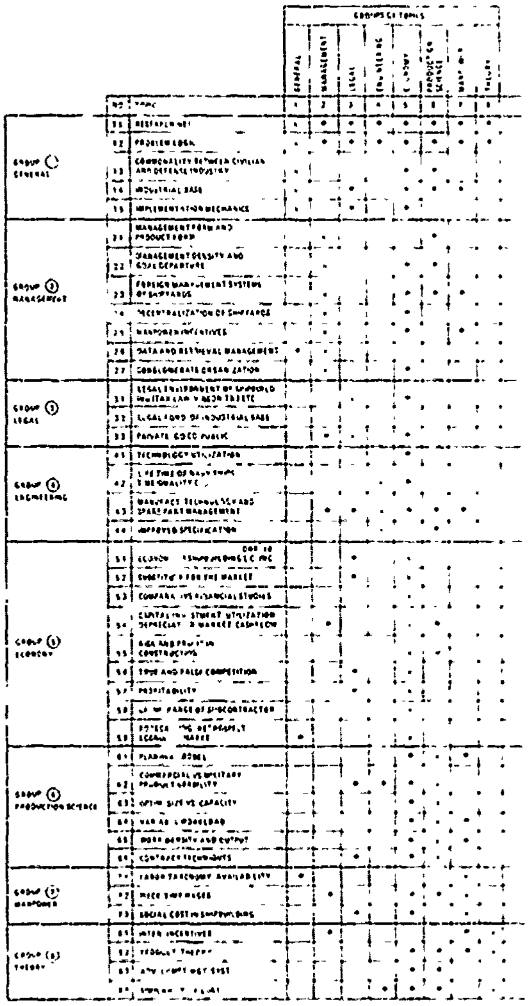
(4) Engineering

Topics in this group are considered essentially engineering problems and have mostly only a secondary connection to other groups.

(5) Economy

Topics in this group are considered essentially economic problems which can often be addressed without considering the immediate impact to other groups. However, in the long run, the economic topics may drive the other groups.

FIGURE 4: PRELIMINARY ORDERING OF TOPICS



(6) Production Science

This group has been formed in order to accommodate all those multidisciplinary problems which are evenly and definitely embedded in more than one group such as in economy and management or management and technology, or in more than two groups.

(7) Manpower

This group encompasses all problems directly related to manpower - also the influences of the manpower problems may be noted in economy, management and other groups.

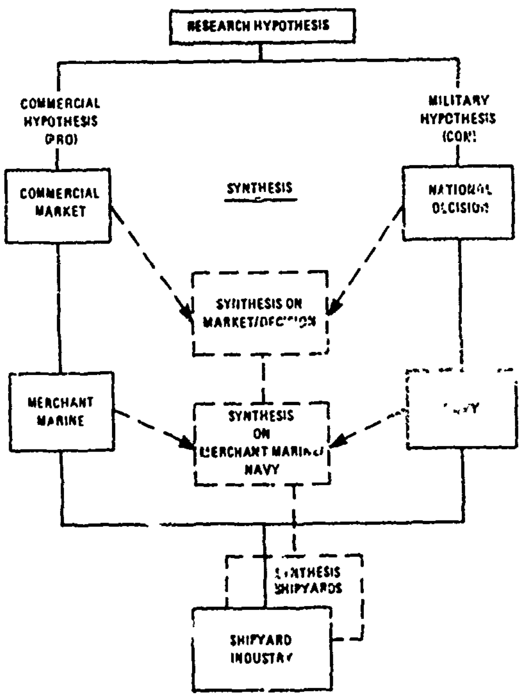
(8) Theory

Few words are more misused than "theory"; it is even more misused than "system". Very often the term is used for everything the reader does not understand or the word is used for "hypothesis" or "assumption". De facto, however, theory indicates the abstraction (or synthesis) of the sum of concrete cases (the examples) of practice. This hint is important to avoid misunderstanding. A preliminary ordering of topics is shown in Figure 4. The figure also established the relationship between the individual topic and the topic group.

4. GENERALIZATION

The concept of starting with a research hypothesis, proceeding toward the formation of research clusters and finally ending up with a synthesis is easily portrayed on the research hypothesis #6 as shown in Figure 5. Having presented this research methodology (as abbreviated in this paper) to the ONR/NAVMAT Acquisition R&D Council, the question has been raised if the same methodology could be generalized so as to be useful for problems acquisition research on a DOD- wide basis.

FIGURE 5: SYNTHESIS TO HYPOTHESIS



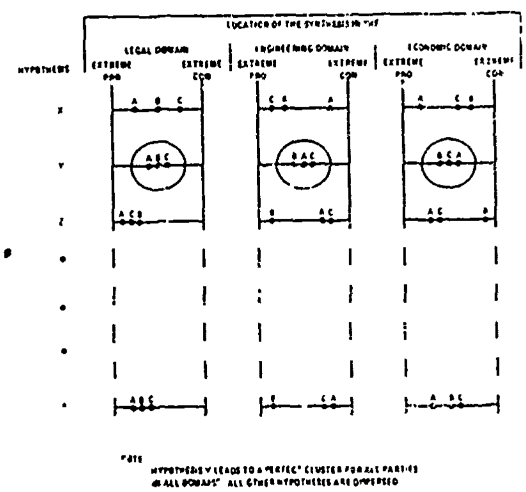
From a purely methodological point of view, I tend toward an affirmative answer. However, from a result-oriented point of view, I am rather reluctant to answer the question one way or the other. Nevertheless, the approach to find the answer shall be sketched in the form of three assumptions as follows:

Assumption #1: Let's assume three parties are interested in developing a unified research methodology in acquisition research and the three parties are searching for a commonality in handling (or implementing) the research result. The three parties shall be A (Navy), B (Army) and C (Air Force).

Assumption #2: Let's assume all parties A, B and C have agreed that the entire spectrum of acquisition research is covered by the Research Hypothesis H-1, H-2...H-n in similar form as outlined previously in section 2 of this paper.

Assumption #3: Let's assume each party, A, B and C, is (a) able to subdivide each hypothesis in its legal domain, its engineering domain and in its economic domain and (b) to locate in each domain the acceptable synthesis with some clarity between the PRO and CON extremes of the research hypothesis. Whenever all those assumptions can find realization, the result can be portrayed as shown in Figure 6.

FIGURE 6: SPECTRUM OF COMMONALITY



In Figure 6, the relative location of the synthesis for each hypothesis is indicated with A, B and C and wherever by a given criterion the locations appear close enough, commonality for A, B and C with regard to a specific hypothesis can be assumed.

Now the methodological problem [illegible] apparent: how can we locate a [illegible] position between the extremes? [illegible] determine the relative posi[illegible] cular group within the spectrum [illegible] bounded by black and white? It can [illegible]ly be done by forcing the solution into [illegible]asurable terms with distinct physical dimensions.

Here we may be back at the epistom[illegible]ical problem which we tried to escape [illegible] beginning.

EPILOGUE

The paper starts with a philosophical sketch about measurement sciences and ends by underscoring an epistomological (and methodological) problem. The beginning leads to a straightforward procedure of how to handle problems related to acquisition research in shipbuilding. The attempt to generalize the procedure - as shown in the last section, may point toward the improbability - if not impossibility - of handling "all" acquistion problems in a uniform way. Of course, this is at the moment a deduction only. It may also be a warning against overoptimism toward DOD-wide conformity.

About the Author:

Dr. Franz A. P. Frisch graduated from the Technical University of Vienna, Austria. He has 30 years' experience in shipbuilding and related subjects. He has worked as a Naval Architect, Guarantee Engineer, Chief Estimator, Production Manager, and Director for Shipyard Planning and Maintenance in Austria, Denmark, Sweden and Germany. In 1956 he was first invited to the U.S.A. to testify on foreign cost and production in subsidy cases before the Maritime Administration. From 1957 through 1962 he was associated with several U.S. Naval Architect firms; was owner's representative in Europe and Japan; conducted studies on transport economy for Venezuela, ICC, and shipowners; was consultant for shipyard planning in Brazil and Europe. In 1963 he joined the staff of CNA (Center for Naval Analysis) and became head of the logistic section and study director; there he originated the FDL ship and ship concept, and was assigned as advisor to the project manager. From 1968 through 1974 Dr. Frisch was faculty member and visiting lecturer at the M.I.T. (Massachusetts Institute of Technology); he lectured on shipyard management, ocean transporation, systems theory in transportation, and in interdisciplinary seminars. In 1972 and 1973 he was consultant to Dubai Drydock, Ltd. for layout of a new shipyard in the Arabian Gulf. Since 1973 Dr. Frisch has been with NAVSEA, mostly involved in special projects. He is also Adj. Professor for V.P.I. (Virginia Polytechnic Institute and State University) teaching graduate courses in Advanced Engineering Economy and Management Concepts.

AN EVALUATION OF THE DEFINITION, CLASSIFICATION AND STRUCTURE OF PROCUREMENT RESEARCH IN THE DOD

Lieutenant Colonel Martin D. Martin, Air Force Logistics Command
Major Gerald R. J. Heuer, Air Force Systems Command
Captain John C. Kingston, Air Force Systems Command
Captain Eddie L. Williams, Air Force Logistics Command

INTRODUCTION

Extensive research has been accomplished in the name of procurement research over the past few years but no definitive, delimited concept has evolved as to what constitutes procurement research (15). A review of the early Department of Defense (DOD) Procurement Symposia "Proceedings" indicated that professionals in the field of procurement called for a definition of the term "Procurement Research" as well as the classification of its characteristics into a model to provide more efficient use of resources. The need existed to clearly define procurement research and to classify its characteristics into a useable conceptual model. Consequently, a study was initiated at the Air Force Institute of Technology to accomplish these goals (4).

Research has been viewed by many in the field as a key to alleviating both existing and future procurement problems (2:1). Senator Stennis, Chairman of the Senate Committee on Armed Services, and Congressman Price, Chairman of the House Committee on Armed Services, reiterated this widely held belief in a joint letter to former Defense Secretary Schlesinger:

"We recognize the value and importance of procurement research as a means of improving the procurement process -- one of the most crucial tasks in Government [10]."

Even though there is a general consensus as to the importance and possible impact of research on the procurement process, procurement research as a discipline has not been clearly defined in existing literature and practice. Also, there is little agreement among the agencies performing this research as to what constitutes procurement research (1:2). There have been several indications as to a possible scope for procurement research; for example, J. M. Malloy, then Deputy Assistant Secretary of Defense for Procurement, described procurement research as essentially "a systematic approach" that follows the scientific method (8:215). However, there has not been a concerted effort to adequately describe what should be included. The result has been that research efforts are categorized as both tentative and diffuse (11:4). Robert Judson, then Deputy Director of Commission Studies, Commission on Government Procurement (COGP), stated that procurement research's

"...first order of priority ... is to construct ... a model so that we can share a consensus on procurement problems, ... a comprehensive studious critical conceptual model for the acquisition process that will give us insights we do not now possess that will help us identify what we don't know [6:93]."

The importance of procurement research and the necessity of defining its role in government acquisition was reaffirmed in an interview with Robert F. Trimble, then Assistant Administrator, Office of Federal Procurement Policy (OFPP) for Contract Administration. He discussed procurement research as follows:

"I've long had an interest in procurement research. I think that it [an attempt to define and classify procurement research] is one that is particularly important because I have seen a considerable amount of confusion regarding what constitutes procurement research. I believe that this matter needs to be clarified so that we can more efficiently utilize the manpower resources that we have in this particular area [15]."

BACKGROUND

In the past, specific areas in procurement research have not been clearly delimited; thus, a historical background must concentrate on the procurement organizations which have developed during the past twenty-five years. The evolution of procurement research has been characterized by changes in organization and procedures. Research, per se, has not been emphasized; rather, the emphasis has been on changes in DOD and Air Force procurement organization which resulted from the need for better procurement methods. The lack of a clear definition of just what procurement research includes made this approach necessary.

In the 1950's, various attempts were made to save money through reorganizing and centralizing purchases of common items. The inertia of old techniques was slow to yield to change, moreover, each military service was "isolated" from the others as far as procurement methods. In the 1960's, some efforts were made to exchange procurement information and to evaluate decision-making during the acquisition process. New approaches were being utilized to improve the management information flow. In the 1970's, many changes occurred in the formal acquisition process. After many long years of inefficiency and redundancy, the national procurement policy, education, and research are becoming centralized

and coordinated under the Federal Acquisition Institute (FAI).

Mr. Robert Judson, then Deputy Director, Commission Studies, Commission on Government Procurement (COGP), in an address to the second DOD Procurement Symposium in 1973 made a challenge to the procurement profession. He said:

"You, gentlemen, have a golden opportunity to redirect procurement research to achieve new goals of excellence. First let's do our research on the problems of research before we lose the chance to make procurement what we want it to be [6:99]."

This challenge was re-emphasized by Dr. John J. Bennett, then Acting Assistant Secretary of Defense (Installations and Logistics) in the Defense Management Journal, July 1975:

"Procurement research is not yet a household phrase in the Department of Defense .... It needs a great deal of attention from management and those people actually engaged in procurement projects [2:1]."

In summary, the important events in the evolution of procurement research start with the Second Hoover Commission in 1953 and continue up to the present time. Key events in procurement reorganization in the 1960's include the reorganization of Air Force Systems Command and Air Force Logistics Command, the Hershey Procurement Pricing Conference, the establishment of the Army Procurement Research Office, and the Commission on Government Procurement. The significant events (thus far) during the 1970's include the six DOD Procurement Symposia, the establishment of the Air Force Business Research Management Center, the addition of a Graduate Procurement curriculum to the Air Force Institute of Technology, School of Systems and Logistics, and a Systems Acquisition Management curriculum to the Naval Postgraduate School, the establishment of the Office of Federal Procurement Policy, and the founding of the Federal Acquisition Institute.

BASIC STUDY OBJECTIVES

The following research objectives of the study are germane:

1. To define procurement research so that a common foundation can be used when discussing this subject.

2. To classify procurement research efforts and functions into various areas and to identify those areas that are most frequently investigated.

3. From these classifications, to suggest a detailed algorithm[1] which can be used for deciding if an effort is procurement research.

METHODOLOGY

A literature review was initiated. It disclosed an increasing interest in the area of procurement research and in defining procurement research, but no suggestions were made as to how this specific area of research should be defined or how it should be classified from a taxonomical standpoint. A search disclosed that content analysis provided a rigorously subjective technique for grouping various procurement efforts: by division of scientific study, by breadth of application, by degree of control, by level of outcome, by level of effort, and by placement in the acquisition and procurement processes.[2] Through a system of summarizing and categorizing, these various groups were used to suggest a definition for procurement research.

The basic research design was divided into five areas:

1. Classifying procurement research efforts and functions into categories and sub-categories.

2. Identifying the areas of procurement research that were most frequently investigated.

3. Defining procurement research in terms of characteristics which were evidenced in the study.

4. Suggesting a taxonomy of procurement research.

5. Designing a procurement research algorithm for evaluating research.

The first three areas of the research design were planned to answer the first and second research objectives. The fourth and fifth design areas were planned to answer the second and third objectives.

The first design area was planned to identify specific scientific and research characteristics of procurement research as evidenced in the "Proceedings". Through content analysis, the articles of the symposia "Proceedings" have been classified into various categories and subcategories of characteristics. These scientific and research characteristics have been correlated with areas of the procurement and acquisition processes.

To satisfy the first and second objectives, the methodological approach of semantic content analysis was adopted. From the universe of

[1]A sequential decision-making process or model.

[2]These categories were adopted from the Straver-Lockwood taxonomy. See references 3 and 14 for further discussion.

research, the population called procurement research was chosen. This population was further narrowed to the sub-population of procurement research as reported in the "Proceedings" of the five DOD Procurement Research Symposia.[3] The analysis consisted of a census of the total sub-population of articles in these "Proceedings".

To validate the coding, a pilot study was accomplished. To enhance the reliability of the research effort, a "target" reliability percentage of 90% was achieved during the pilot study. Additionally, during the analysis, random samples of articles coded by one researcher were recoded by a second researcher to insure consistent and standard results.

After coding the data for each "Proceedings", a relative frequency count of occurrences under each digit code was tabulated. Each digit in the seven-digit code represented a category of science, research, the acquisition process, or the procurement process. The first digit was coded to show the division of science used in the research. The second digit was coded to show the breadth of application of the research techniques used. The third digit was coded to identify the amount of control used by the researcher and where the research was conducted. The fourth digit was coded to determine the level of outcome of the research effort; what could be said about the area studied, did it describe a situation, or could a model be developed to predict future events? The fifth digit was coded to indicate the level of effort used in the research; i.e., the amount of time and depth of effort necessary to accomplish the research. The sixth and seventh digits were coded to indicate the phases of the acquisition and procurement processes with which the research was concerned.

In the second design area, the results of the content analysis were combined into relative frequency distributions. Each sub-category was analyzed to determine those areas of procurement research which were most frequently investigated and which characteristics were most prevalent in the population.

The third research design area, defining procurement research in terms of characteristics evidenced in the study, was addressed using the tabulated data. The characteristics of research and science derived from content analysis were combined with information obtained from literature reviews and personal interviews to develop a tentative conceptual definition of procurement research.

The fourth area of research design was planned to classify procurement research efforts into various areas, as stated in the second objective, and to suggest a detailed procurement taxonomy. Information for this area was gathered from existing literature and personal interviews (7, 9, 12 and 13).

In the fifth research design area, the designing of a detailed algorithm was envisioned to meet the third objective. This algorithm could be employed in determining whether an effort within DOD is related to procurement and whether it is research. The algorithm was derived from information gained from the content analysis, literature reviews and personal interviews as noted in the aforementioned paragraph.

FINDINGS

Data from the content analysis of the "Proceedings" have been tabulated, and a taxonomy and algorithm have been developed. The results of the content analysis, which are listed in Table 1, showed the following primary areas of emphasis as related to the selected criteria.

TABLE 1 - SUMMARY OF FINDINGS

1. DIVISION OF SCIENCE: SOCIAL (46%)
   ABSTRACT/SOCIAL COMBINED (47%)
2. BREADTH OF APPLICATION: APPLIED (62%)
3. DEGREE OF CONTROL: LIBRARY (54%)
4. LEVEL OF OUTCOME: DESCRIPTIVE (95%)
5. LEVEL OF EFFORT: PROFESSIONAL PAPER/RESEARCH MONOGRAPH (68%)
6. PHASE OF THE ACQUISITION PROCESS:
   MORE THAN ONE PHASE (60%)
   NOT CONCERNED WITH THE ACQUISITION PROCESS (47%)
7. PHASE OF THE PROCUREMENT PROCESS
   PRE-AWARD (47%)
   MORE THAN ONE PHASE (35%)

As corollary information to the content analysis, the researchers noted the source of each article. Of the one hundred fourteen (114) articles, the source distribution is recorded in Table 2.

TABLE 2 - ARTICLE SOURCE DISTRIBUTION

AGENCY	NUMBER	PERCENTAGE
DOD	9	8%
ARMY	19	17%
NAVY	14	12%
AIR FORCE	39	34%
NON-DOD		
Federal Agencies	11	10%
Private Business/ Universities	22	19%

The initial taxonomy was divided into five levels of procurement research. Each level subdivided the previous level into more

[3] The research for this study was conducted prior to the publication of the Sixth DOD Procurement Research Symposium.

specific areas where procurement research can be identified.

CONCLUSIONS

The results of the research suggested the following definition of procurement research:

Procurement research (and acquisition research) is an applied science using the characterisrics of the social sciences in combination with mathematical sciences to solve procurement problems. It tends to rely heavily on the use of previously gathered data to seek solutions to problems, equally dividing its efforts between the acquisition process and the procurement process. In the acquisition process, emphasis is placed on the total process; while in the procurement process, emphasis is on the pre-award phase in an effort to identify cost-related problems.

The results of the content analysis are limited to the actual sub-population itself, but the sub-population of the "Proceedings" represents an important cross-section of recent DOD procurement research experience. Information derived from the analysis of this sub-population can suggest important characteristics and relationships of other procurement research efforts.

The areas of emphasis in the procurement research of the "Proceedings" were identified in the content analysis. Procurement research was characterized as a social science with abstract science combined more often than not. Its structure is delimited in Figure 1. Efforts were primarily applied to solving problems. The research was primarily accomplished through a selected aggregation of information (library) and the level of outcome was descriptive. In the sub-population, the level of effort was primarily a professional paper/research monograph. The relationship of procurement research with the acquisition process showed that efforts generally involved more than one phase of the acquisition process or were not concerned with the acquisition process at all. Emphasis in the procurement process was primarily in the pre-award phase with many articles dealing with more than one phase.

The definition of procurement research and the classification of the characteristics of procurement research were combined with the information from the interviews and the literature review to develop the taxonomy. The emphasis for the taxonomy has been to cover all possible areas of procurement research as suggested by various information sources.

The procurement process is the foundation upon which procurement research is based (see Figure 2). Procurement research can involve both the procurement and acquisition processes and their interrelationship. Therefore, to construct a taxonomy of procurement research focusing primarily on the procurement process, it was necessary to build a model of this process. Since procurement research is concerned with the procurement process and the procurement process as an integral part of the acquisition process, a taxonomy of the procurement process can serve as a foundation for a taxonomy of procurement research. The areas and issues pertaining to these processes, therefore, also pertain to procurement research. These areas and issues, as related to the procurement process were the focal point of this research and the descriptors of the research taxonomy. Content analysis provided the general characteristics of procurement research and a partial structure of the procurement processes. However, to complete the taxonomy of the process, it was necessary to conduct interviews and make further literature reviews.

The taxonomy was constructed to display five levels of the procurement process. The first level is the procurement process. The second level is the three phases (Pre-Award, Award, and Post-Award). The third level is comprised of the cycles that make up each of the phases. The fourth level is a continuum of events (Procurement Continuum) that describe the necessary actions pertinent to the life of a "procurement". The fifth level, the lowest level presented, is composed of a number of issues related to each of the events. (See Figure 3.)

The research effort was adjusted as the researchers discovered new information that impacted the definition and the taxonomy. The taxonomy developed by the researchers is outlined in Figure 4. Lastly, an algorithm was developed (see Figure 5) which followed the format of a decision flow chart with eight decision points, all of which (except one) must be answered with an affirmative response before an effort can be considered procurement research. These eight decision points are as follows:

1. <u>Is the effort concerned with satisfying a perceived DOD need?</u> Is the effort attempting to solve a problem, provide insight into an issue, or describe a problem within the DOD? If it is not, it should not be considered for further research.

2. <u>Is the research effort concerned with the acquisition process?</u> If the answer to this is negative, a second question is asked, "Is the research concerned with the procurement process?" (See Figure 4 and Table 3.) If the answer to this is positive, the effort is retained for further analysis.

3. <u>Is the research concerned with the procurement process?</u> Here, the efforts judged affirmatively, using question 2, are analyzed according to the procurement taxon[illegible] ques-tions as set forth in Table 3.

4. <u>Does the effort suggest a method for improving the knowledge associated with the</u>

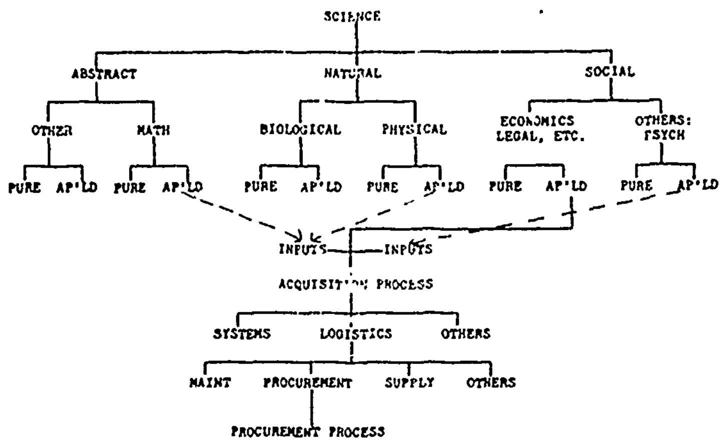


FIGURE 1. THE DELIMITATION OF PROCUREMENT RESEARCH

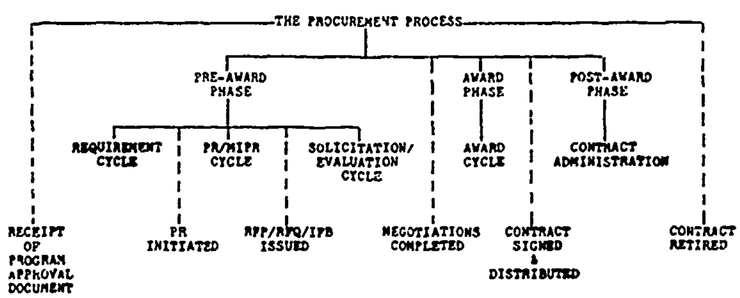


FIGURE 2. THE PROCUREMENT PROCESS (PHASES)(9)

LEVEL 1: PROCESS

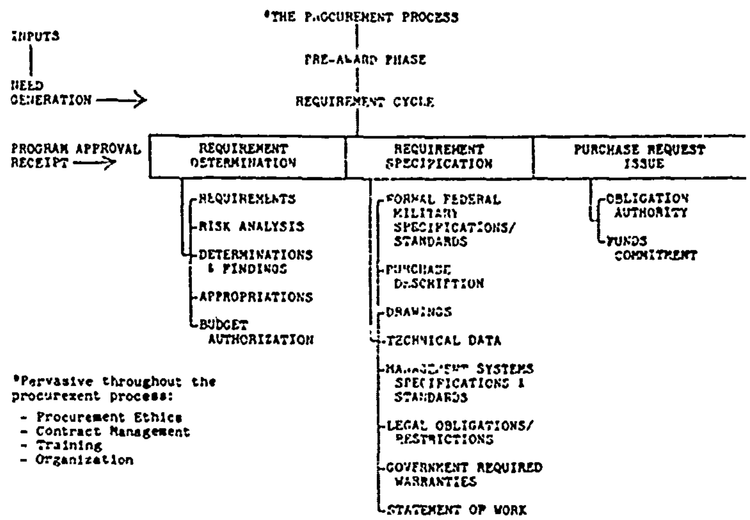
LEVEL 2: PHASE

LEVEL 3: CYCLE

LEVEL 4: EVENT

LEVEL 5: ISSUE

FIGURE 3. LEVELS OF THE PROCUREMENT PROCESS



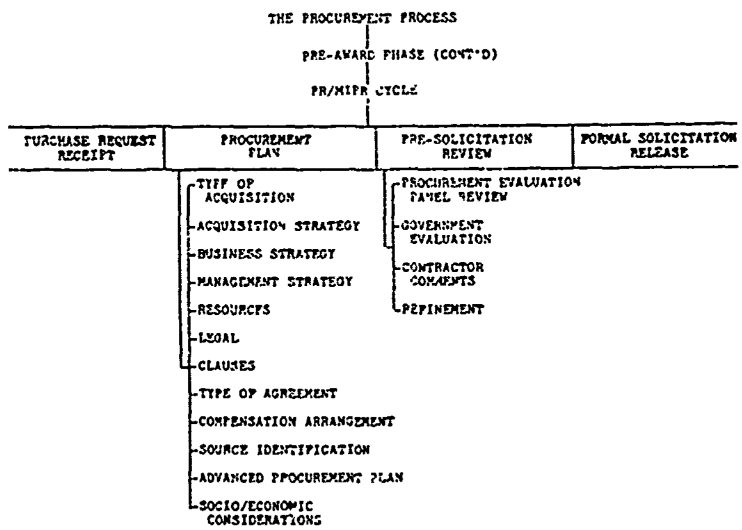
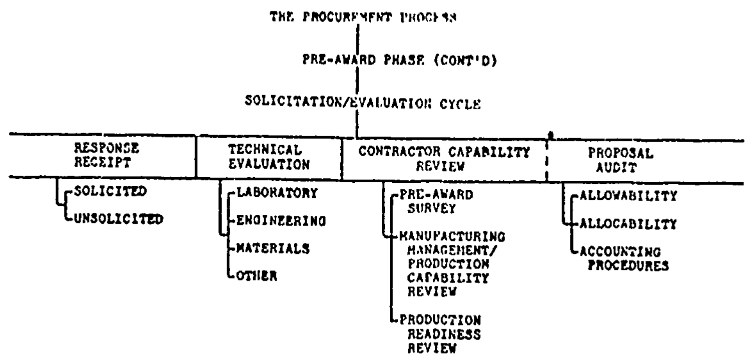
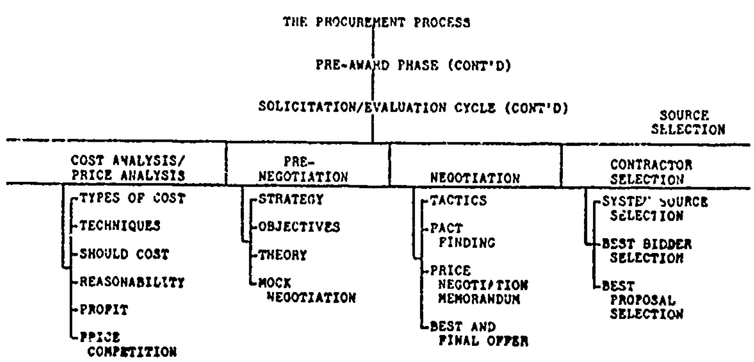


FIGURE 4. A PROCUREMENT TAXONOMY



*Broken line denotes possible overlapping events or that another sequence may be possible.



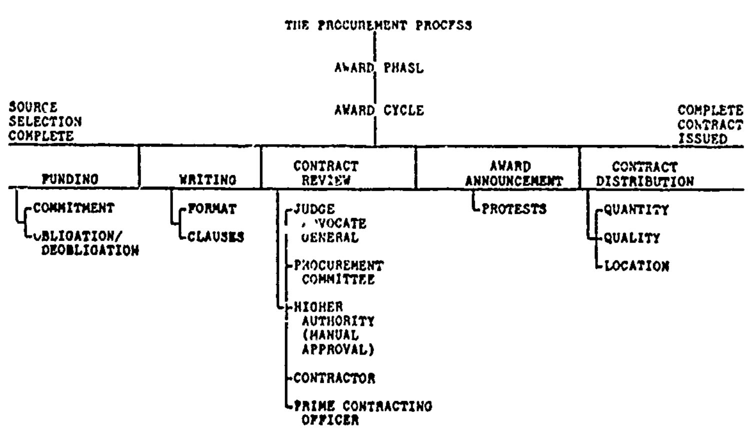


FIGURE 4 (CONT'D). A PROCUREMENT TAXONOMY

THE PROCUREMENT PROCESS
- POST-AWARD PHASE
  - CONTRACT ADMINISTRATION CYCLE
    - ASSIGNMENT
      - AGENCY
      - CONTRACTING AUTHORITY DELEGATION
      - SECONDARY DELEGATIONS
      - DEGREE OF GOVERNMENT INVOLVEMENT/ ENGAGEMENT
    - SYSTEM COMPLIANCE
      - PURCHASING
      - QUALITY
      - PROPERTY
      - WAGES AND SALARIES
      - RETIREMENT
      - FINANCIAL COSTS
      - SOCIO/ECONOMIC
    - PERFORMANCE MEASUREMENT
      - COST CONTROL
      - TECHNICAL AND PERFORMANCE CONTROL
      - SCHEDULE CONTROL
      - FUNDS CONTROL
    - QUALITY ASSURANCE
      - MANAGEMENT APPROACHES
      - INSPECTION
      - CORRECTIONS OF DEFECTS
      - ACCEPTANCE

THE PROCUREMENT PROCESS
- POST-AWARD PHASE (CONT'D)
  - CONTRACT ADMINISTRATION CYCLE (CONT'D)
    - CONTRACT MODIFICATIONS
      - UNILATERAL
      - BILATERAL
      - EQUITABLE ADJUSTMENTS
    - DELIVERY
      - TIMELINESS
      - QUANTITY
      - DESTINATION
    - PAYMENT
      - CUTBACKS
      - ESCALATION
      - REBATES
      - PARTIAL
      - ADVANCE
      - PROGRESS
      - FINAL
      - DISCOUNTS
    - WARRANTIES
      - STANDARD
      - COMMERCIAL
      - RELIABILITY IMPROVEMENT

.. PROCUREMENT PROCESS
- POST-AWARD PHASE (CONT'D)
  - CONTRACT ADMINISTRATION CYCLE (CONT'D)
    - DISPUTES
      - PROCEDURES
    - REMEDIES
      - TERMINATION
      - WITHHOLD PAYMENT
      - CONTRACTOR ADJUSTMENT
      - OTHERS
    - COMPLETION
      - RECOVERY OF UNUSED FUNDS
      - CLOSEOUT
      - RETIREMENT
  - CONTRACT RETIRED
    - POST CONTRACT
      - RENEGOTIATION

FIGURE 4 (CONT'D). A PROCUREMENT TAXONOMY

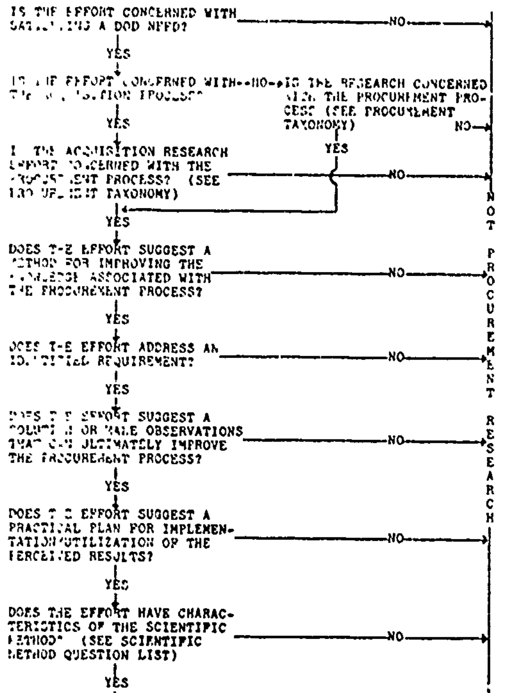


FIGURE 5. PROCUREMENT RESEARCH ALGORITHM

TABLE 3

CRITERIA FOR DETERMINING WHETHER A RESEARCH EFFORT IS PROCUREMENT RELATED

1. IS IT CONCERNED WITH ISSUES PERVASIVE TO THE PROCUREMENT PROCESS (PROCUREMENT ETHICS, CONTRACT MANAGEMENT, TRAINING, ORGANIZATION)?
2. IS IT RELATED TO REQUIREMENTS DETERMINATION?
3. IS IT CONCERNED WITH REQUIREMENTS SPECIFICATION?
4. IS IT CONCERNED WITH PR ISSUANCE?
5. IS IT CONCERNED WITH OTHER ASPECTS OF THE REQUIREMENTS CYCLE?
6. IS IT RELATED TO THE RECEIPT OF A PR?
7. IS IT CONCERNED WITH PRE-SOLICITATION REVIEW?
8. IS IT CONCERNED WITH FORMAL SOLICITATION ISSUANCE?
9. IS IT CONCERNED WITH OTHER ASPECTS OF THE PR/MIPR CYCLE?
10. IS IT CONCERNED WITH THE RECEIPT OF RESPONSES TO SOLICITATION?
11. IS IT RELATED TO THE TECHNICAL EVALUATION OF RESPONSES?
12. IS IT CONCERNED WITH PROPOSAL AUDITS?
13. IS IT CONCERNED WITH COST ANALYSIS/PRICE ANALYSIS?
14. IS IT CONCERNED WITH PRE-NEGOTIATION ISSUES?
15. IS IT CONCERNED WITH CONTRACT NEGOTIATION?
16. IS IT CONCERNED WITH CONTRACTOR SELECTION?
17. IS IT CONCERNED WITH OTHER ASPECTS OF THE SOLICITATION/EVALUATION CYCLE?
18. IS IT CONCERNED WITH SOME ASPECT OF THE PRE-AWARD PHASE?
19. IS IT CONCERNED WITH CONTRACT FUNDING?
20. IS IT CONCERNED WITH CONTRACT WRITING?
21. IS IT CONCERNED WITH THE REVIEW OF A CONTRACT PRIOR TO ANNOUNCEMENT AND FINAL SIGNATURE?
22. IS IT CONCERNED WITH AWARD ANNOUNCEMENT PROCEDURES?
23. IS IT CONCERNED WITH CONTRACT DISTRIBUTION PROCEDURES?
24. IS IT CONCERNED WITH OTHER ISSUES OF THE AWARD CYCLE OR AWARD PHASE?
25. IS IT CONCERNED WITH THE ASSIGNMENT OF THE CONTRACT FOR ADMINISTRATION?
26. IS IT CONCERNED WITH CONTRACT SYSTEM COMPLIANCE?
27. IS IT CONCERNED WITH PERFORMANCE MEASUREMENT OF THE CONTRACTOR?
28. IS IT CONCERNED WITH QUALITY ASSURANCE/PRODUCT ACCEPTANCE?
29. IS IT CONCERNED WITH CONTRACT MODIFICATIONS?
30. IS IT CONCERNED WITH PRODUCT DELIVERY?
31. IS IT CONCERNED WITH CONTRACTOR PAYMENT?
32. IS IT CONCERNED WITH CONTRACT WARRANTIES?
33. IS IT CONCERNED WITH CONTRACT DISPUTES?
34. IS IT CONCERNED WITH REMEDIES RESULTING FROM CONTRACT DISPUTES?
35. IS IT CONCERNED WITH CONTRACT COMPLETION AND CLOSE-OUT?
36. IS IT CONCERNED WITH ANY OTHER ISSUES OF THE CONTRACT ADMINISTRATION CYCLE OR THE POST-AWARD PHASE?
37. IS IT CONCERNED WITH POST CONTRACT ISSUES SUCH AS RENEGOTIATION?

IF THE ANSWER TO ANY OF THE ABOVE QUESTIONS IS "YES", THEN THE EFFORT IS RELATED TO PROCUREMENT.

procurement process? Three general questions can be asked of the research effort:

a. Does it increase the uncertainty of the procurement process?

b. Will the suggested results of the research effort provide more knowledge of the procurement process, knowledge of an area that has not been investigated before?

c. Does the effort clarify events, areas, or issues in the process?

5. Does the effort address an identified requirement? Before passing judgment on the effort, a review by relevant procurement personnel should be obtained to establish the validity of the undertaking. If judged negatively, the effort should be discarded or held for later evaluation. If judged affirmatively, the effort passes on to the next algorithm question.

6. Does the effort suggest a solution or make observations that can ultimately improve the procurement process? An effort that is classified as procurement research should be directed toward the improvement of the procurement process.

The key to this decision point in the algorithm is that the research effort contributes to the improvement of the procurement process either through a solution to an existing problem or through observations that may lead to the understanding and solutions to future problems.

7. Does the effort suggest a practical plan for implementation or utilization of the perceived results? An effort may be directed at the ultimate improvement of the procurement process. It may suggest a solution to an existing problem or it may be used as a "stepping stone" to solutions of future problems. However, if the effort suggests using implementation/utilization procedures and/or techniques that would be impractical, the effort is suspect.

Application of this decision point requires a word of caution. Implementation/utilization plans suggested by some research efforts may be deemed impractical now, only to be proven practical at some future point in time. This fact may require that the final determination of whether some research efforts are procurement research needs to be deferred to a later date.

8. Does the effort have characteristics of the scientific method? Determination of whether the effort follows the scientific method is made by either the research analyst and/or the procurement manager subjecting the effort to the series of questions listed in Table 4. (If the effort is proposed, questions (1-10) would be applicable, but if the effort was completed research, all questions would be applicable.) If negative answers were obtained, the effort should be discarded, or returned to the researcher for reclarification and rework and then returned for further analysis by the research approving agency.[4]

This algorithm suggests that a certain level of effort be undertaken by the researchers who proposes the study prior to its submission to the approving agency for acceptance. Resources available to the procurement research community are necessarily limited and need to be applied only to pertinent research proposals. Time and funds cannot be ill-spent on poorly defined research proposals that return marginal results or have no applicability to the procurement process.

TABLE 4

SCIENTIFIC METHOD QUESTION LIST

1. DOES IT DEFINE THE PROBLEM?
2. DOES THE EFFORT SURVEY EXISTING PERTINENT LITERATURE?
3. HAS THE RESEARCHER EVALUATED PAST STUDIES FOR APPLICABILITY TO HIS EFFORT?
4. DOES THE EFFORT BUILD ON PREVIOUSLY DEVELOPED KNOWLEDGE?
5. IS THE SCOPE DEFINED AND SPECIFIED, AND ARE THE SPECIFIED OBJECTIVES TO BE MET LISTED?
6. DOES THE EFFORT SUGGEST THE TESTING OF A HYPOTHESIS OR THE ANSWERING OF A RESEARCH QUESTION?
7. IS THERE A SPECIFIED PLAN?
8. DOES THE EFFORT LIST ASSUMPTIONS/LIMITATIONS?
9. IS THE METHODOLOGY LOGICAL AND APPROPRIATE FOR THE OBJECTIVES SPECIFIED?
10. DOES THE EFFORT GATHER DATA AND/OR FACTS?
11. ARE THE DATA VALID AND RELIABLE?
12. DOES THE EFFORT REPORT, DESCRIBE, PREDICT OR EXPLAIN?
13. DO CONCLUSIONS LOGICALLY FLOW FROM THE DATA?
14. CAN THE EFFORT BE REPLICATED TO ACHIEVE CONSISTENT RESULTS?

WHAT PROCUREMENT RESEARCH SHOULD BE ...

The previously discussed research efforts concentrated on what procurement research is and has been during the past few years. From exposure to the information that was reviewed in this effort, the research team gained an insight into procurement research and herein suggest what procurement research should be:

1. It should concern the acquisition or procurement processes. Research accomplished by procurement researchers that does not involve the procurement or acquisition processes makes an inefficient use of limited resources.

2. Procurement research should seek solutions to procurement problems. Procurement research should be applied research; it should be concerned with seeking solutions to problems faced by procurement managers and personnel.

3. Procurement research should be cost effective. Procurement researchers should concern themselves with a cost analysis of their own work. If the research can be performed at a lower cost external to the originating research agency, then the effort should be accomplished externally.

4. Procurement research should follow the scientific method. The "Proceedings" indicated that procurement research did follow the scientific method in its approach to problem solving. Future research should use the same procedures/techniques.

5. Procurement research should be unbiased. Procurement research should report true findings, not "channel" results to suit the researchers. The researcher should apply rigorous subjectivity to his research and remain unbiased in his analysis.

6. Procurement research should make use of the best analytical methods. Poor research techniques waste resources and provide weak

[4]Managerial questions as to "who" is going to accomplish the research or "where" it should be done, were not addressed by this algorithm. They should be answered (asked) by the research manager only after the effort has been identified as "procurement research". These questions naturally follow this algorithm and not only address the issue of "who" and "where", but also "when" it will be studied (if not ongoing) and "what funds are available".

solutions to problems that may require strong remedies. A careful, thorough evaluation of a procurement research problem can suggest the best analytical method to use in the effort.

7. Procurement research should be original and not redundant. Prior to doing research, procurement people should review previous studies and ascertain whether a new research effort is justified or whether the findings of a previous study are sufficient.

8. Procurement research should be shared. Central procurement information storage facilities should be accessible to all procurement research organizations, internal and external to the Government. Results should be publicized, such as those found in the "Proceedings". Only through the sharing of information can the redundancy be reduced and resources saved.

9. Procurement research should be simple, yet accomplish the task. Procurement research should accomplish its specific task in the most direct method possible. It should not confuse the problem-solving methodology with techniques designed to impress the requester while hiding the path the researcher used to seek his solution. The approach used by the researcher should be "fair and reasonable" to all parties.

COROLLARY OBSERVATIONS ON PROCUREMENT RESEARCH

Experience gained during the course of this research may prove enlightening to subsequent researchers. These observations are summarized as follows:

1. An increasing level of interest in procurement was noted as a definite trend during the past few years.

2. The annual DOD Procurement Research Symposium offers an excellent means for sharing procurement research information; however, often other research efforts and results are not shared.

3. Procurement researchers generally do not share their current progress or projects.

4. Often the method or technique that resulted from the research effort could be applied to other problem situations, but the research itself was done strictly in response to one problem. General research to improve the overall acquisition and procurement processes was lacking.

5. The present information retrieval systems do not provide a totally accessible system to the researcher.

These corollary observations would be incomplete without some suggestions or recommendations for improvement. Indication of a deficient area implies that better methods are perceived for getting the task done; the next section offers recommendations for improving procurement research.

RECOMMENDATIONS

Further studies must be made and current methods must be changed in order for procurement research to be improved. The results and conclusions from this study suggest starting points for further studies and alternative courses of action for current methods in procurement research. Eight recommendations for further study and procurement research improvement follow:

1. Add research studies with a longer range perspective to present problem/response type studies. The addition of some longer range research in procurement may identify influential factors that are not evident in the short-range, reactive approach.

2. Areas of procurement research effort, significant research progress, and research results should be shared with the procurement community. The area of sharing information on procurement research is essential to the DOD procurement community. Further research should be done: (1) to research the extent of the problem of how many completed procurement research studies do not get into the DOD information retrieval systems and to correct this deficiency in information flow, and (2) to find a means to identify current DOD procurement efforts in progress and to publicize this information on a regular basis.

3. The DOD should adopt the taxonomy developed in this research effort as a common taxonomy of procurement research for use by its agencies. A standardized taxonomy of procurement research would allow researchers from all DOD agencies to establish a common framework for communication. Not only would researchers be on a common base, but procurement people could understand research results from other agencies and possibly apply new and better techniques to their own work. The procurement research taxonomy presented in this study could be a logical starting place from which a common DOD taxonomy could be expanded. Finally, a common taxonomy could be used as a data base for assigning descriptors to procurement research in a computerized information system.

4. The procurement research taxonomy that is suggested in this study should be critically analyzed and expanded. The taxonomy is an attempt at categorizing the procurement process and the field of procurement research. Through further study, this taxonomy could be validated and expanded to include requirement definition and use as they impact upon procurement.

5. Further algorithms for conducting procurement research and for deciding whether to research procurement problems should be constructed and used. During the construction of the algorithm, the researchers had much difficulty in establishing a perspective from which to construct the algorithm. Procurement research can be viewed in terms of a given output or ongoing process, a method for conducting the research, or a method for deciding whether a procurement problem should be researched by an organization/individual. Future efforts should research these two areas to provide guidelines for conducting the procurement research process and for making the important decision of whether or not to undertake a research effort.

6. A model for DLSIE (Defense Logistics Systems Information Exchange) abstracts should be developed so that key words would provide ready relevant information. Research should be done to develop a model for writing DLSIE abstracts so that a content analysis of an abstract would determine key words, words similar to the phases, cycles, events, and issues of the taxonomy presented in Figure 4. Procurement researchers could then identify those studies relevant to their areas of specific research from this content analysis of the abstracts.

7. A sequential analysis of procurement research efforts should be performed. Hood and Strayer (5) suggested that procurement research, as a developing discipline, can be portrayed as transitioning six development phases in a sequential evolutionary process from a new discipline to full maturation. The significance of this evolutionary process and its developmental phases is that each phase differs in terms of the kinds of questions or issues addressed and types of research activity conducted within each phase.

8. Research should be done to prioritize those "issues" of the procurement research taxonomy that offer the greatest opportunity for cost savings and improvement. An analysis at the "issue" level of the procurement research taxonomy could identify those areas that are costly to implement, difficult to administer, and subject to frequent delay, as well as those areas that offer the greatest benefits to the DOD, the public, and industry. A priority system of procurement research issues would identify those areas that should receive the most research emphasis. Limited resources could be applied to "issues" from the top down so that the most important areas are researched first.

SUMMARY

The result of this effort is only the first step toward defining and structuring procurement research. It will be up to the procurement community as to whether this initial effort is accepted and used. This definition and taxonomy offer a basis which researchers can use to more closely define procurement research and its relationship to the procurement process, while the algorithm provides the researcher or procurement manager with a logical process to evaluate the research effort as to its applicability to procurement.

Lastly, observations on "What Procurement Research Should Be ..." and recommendations for further research were offered to the procurement community as a means of accelerating the evolutionary process of procurement research.

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CONTRACT CYCLE IMPROVEMENT

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LEADTIME MANAGEMENT, A KEY TO MATERIALS MANAGEMENT

Captain Robert W. Menestrina, USAF, MS, CPL, CPCM, CPM

FOREWORD

This paper is a condensed version of a paper presented to the 12th Annual International Symposium of the Society of Logistics Engineers, August, 1977. (6) Additional information on this subject is available from the author upon request.

Opinions expressed herein are solely those of the author and are not those of the United States Air Force.

INTRODUCTION

The reason for exploring this subject was the generally perceived failure of the Air Force Local Purchase System to meet the Department of Defense (DOD)leadtime standards for order and ship time.[1] This perceived failure was also recognized by requisitioners who were aggravating the situation by increasing the priority of their local purchase requisitions.

After careful study and data collection (5) several findings emerged concerning local purchase leadtime management: 1. The DOD order and ship time standards are based upon a normative concensus of expert logisticians' opinions of what leadtimes ought to be, rather than some positive measure of actual leadtimes. 2. Current DOD order and ship time standards are averages and not upper control limits. 3. Actual averages are being compared with the DOD standards, but a truncation rule used to calculate the actual averages causes a large downward bias in the calculated averages.

The conclusion of this preliminary study was that current order and ship time standards and the current heavily biased truncated average do not provide adequate tools to identify and manage local purchase leadtime.

This paper is an attempt to develop the tools and methodology necessary to a Department of Defense installation level or a Commercial plant level leadtime management system. We will discuss some general management concepts, the use of statistics to reduce uncertainty, current leadtime research, special considerations in the plant level environment, and a case study. We will then draw conclusions from this discussion.

1. Order and ship time is measured from the date the customer submits a requisition until the date the materials are received by the supply activity.

GENERAL MANAGEMENT CONCEPTS

The manager combines resources (men, money, and materials) uses the classic management functions (plan, organize, staff, direct and control) and trades off production factors (cost, quality and time) to make his enterprise productive. He must also manage his function within an environment of constraints and uncertainty. This relationship can be visualized in Exhibit 1, below.

EXHIBIT 1

THE MATERIALS MANAGER FUNCTIONS

Combine Resources	Use Mgmt Functions	Trade Off Prod. Factors	Minimize Effects of	To Produce
Men	Plan	Cost	Constraints	Output
Money	Organize	Quality	and	
Material	Staff	Time	Uncertainty	
	Direct			
	Control			

The manager has developed cost and quality management systems to control only two of these production factors. This paper addresses a management system for the third production factor — Time.

In addition, the uncertainty of leadtime planning is a key reason micro-analysis of leadtime is critical for effective base and/or plant level materials management.

By assuming leadtime is constant, the materials manager is acting counterproductively because his assumption of a fixed leadtime increases uncertainty and increases costs.

A good example of the problem caused by assuming constand leadtimes can be found if we look at the Economic Order Quantity model (EOQ). The EOQ reorder point is a function of both the rate of demand and a reorder leadtime that is usually assumed to be fixed. If the actual leadtime varies and is greater than the assumed fixed leadtime, we have induced unforeseen backorders and have increased costs.

LEADTIME AND UNCERTAINTY

The manager can reduce uncertainty with the help of statistics, probability theory, and control limits. If the manager can form subgroups with similar traits that approximate a normal distribution, he can assume a normally distributed leadtime. By using a normally distributed mean and standard deviation, he can then identify and possibly reduce uncertainty regarding expected leadtime.

For example, if after data collection, a normally distributed group is found to have a mean of 40 days and a standard deviation of 10 days, we can develop a table showing the probability of one item being delivered on or before a specific number of days after the order was placed. (Exhibit 2)

EXHIBIT 2

SINGLE ITEM LEADTIME PROBABILITY

Mean (M) Std Dev (SD)	Example (Days)	P (Success)
M-1 SD	30	16%
MEAN	40	50%
M+1 SD	50	84%
M+2 SD	6	98%
M+3 SD	70	99%

This information can also be used to improve projections of delivery of multi-item bills of material. The probability of success for on time delivery of a multi-item bill of material is extremely sensitive to the company's leadtime planning philosophy. This can be demonstrated by using the previous example and calculating the probability of on time delivery success for multi-item bills of material. (Exhibit 3)

EXHIBIT 3

MULTI-ITEM LEADTIME PROBABILITY

Planning Policy	Example (Days)	P(Success) Equals $(P(S))^i$ When i = No. of Items		
		ONE	FIVE	TEN
M-1 SD	30	16%	.00%	.00%
MEAN	40	50%	3%	.00%
M+1 SD	50	84%	42%	17%
M+2 SD	60	98%	90%	82%
M+3 SD	70	99%	95%	90%

In this example, the company would have only a 3% chance of obtaining five items within 40 days, but they could improve the probability of on time receipt if they planned for a leadtime greater than the mean leadtime. Currently, DOD base level customers are only told the average order and ship time from a source of supply. As shown above, the probability of delivery by the average leadtime is only 50% for one item and this probability rapidly diminishes if the customer has a multi-item bill of material. By developing a planning leadtime policy that considers probability, we can have a powerful tool to cut costs and reduce uncertainty.

Developing a control limit provides the final tool needed to design a viable leadtime management control system. If in our example, the company chose to audit every demand those leadtime exceeded the mean and three standard deviations (after 70 days) then the company would only need to audit one percent of the individual demands. Such a control limit would pinpoint the worst cases, require minimum audit support, and identify major problems. By solving problems relating to these extreme cases, not only will the average leadtime be reduced, but the solution probably will have general application to many of the other 99% of demands.

CURRENT LEADTIME RESEARCH

Current leadtime research is very limited. (See Bibliography) It is related to production quantities, central purchase activities, or nation wide studies of commodities or industries. But these studies may not directly apply to a base or plant level materials manager because of their Macro viewpoint, one-time data collection, large staffs to apply complex research techniques, emphasis on production quantities, and the different organizational environment of a centralized purchase activity. Because of these differences, we must identify special considerations in the environment of the base or plant level materials manager before we can design a leadtime management system.

SPECIAL CONSIDERATIONS

The local environment of the base and plant level materials manager is different from that of corporate level management. Because of this local environment, it is important to address the following special local considerations when designing a base or plant level leadtime management system.

1. Simplicity: As in any system requiring data collection, the simpler and more understandable the entire system, the more likely the people who must provide the data will cooperate and provide accurate data.

2. Cost Effectiveness: Cost cannot exceed benefits.

3. Computerization: A computer is helpful, but not essential. The author used a hand calculator (HP-80) to calculate the statistics in the case study.

4. Variability: The first line materials manager is concerned with an extremely wide and variable range of demands.

5. Statistical Process Control Techniques: The materials manager can use a leadtime management system to identify groups with unusually high leadtimes.

6. Sensitivity: The plant level leadtimes are extremely sensitive to both external changes (OSHA or oil crisis) and internal changes (absence of key employees).

7. Criticality of Small Orders: The plant level material manager is as concerned with critical small orders as he is with production quantity orders.

8. Large Number of New First-Time Demands.

9. Standard Leadtime Definition: A standard leadtime definition must be agreed to by all customers and functional managers.

10. Continuous Data Collection: Because of the criticality of small orders and the sensitivity to change, leadtime data collection must be continuous.

11. Process Management: The leadtime management system is a process management rather than a project management technique. The manager is able to control a multitude of demands by use of a limited number of control points.

12. The Materials Acquisition Assembly Line: All materials management personnel are part of a paper assembly line called "materials acquisition process". This is a key concept.

13. Coordination: The plant level materials manager has the advantage of more opportunities for close coordination with his functional counterparts.

14. Suboptomizing Leadtimes: The overall leadtime should be minimized rather than minimizing only the leadtime of some segment of the materials acquisition process.

15. Wide Range of Improvements: The various functional managers have many tools to improve leadtimes, but changes should be coordinated and controlled to prevent suboptomization and/or the formation of new problems.

16. System Study Improves Leadtimes: Even it a full leadtime management system is not practicable for a specific base or plant, the act of system study will cause improved leadtimes.

CASE STUDY

The concepts listed above were used in a case study of 7500 actual local purchase demands during a nine month period on an Air Force Base. (5) The results of this case was that item leadtimes were dramatically improved, material acquisition system discipline improved, as did functional cooperation. All the participants in the study had a better understanding of the material acquisition process, and they better understood the need for realistic planning leadtimes. These findings were so positive, the author strongly urges expanded development and use of leadtime management systems.

HOW TO DESIGN A LEADTIME MANAGEMENT SYSTEM

After all the above considerations are included, a leadtime management system can be designed by the materials manager. Listed below are 14 important points to use when designing a leadtime management system:

1. KISS (Keep It Simple, Stupid)
2. Group like items.
3. Track new first-time demands separately,
4. Track repetative demands separately.
5. Track leadtime overtime.
6. Calculate average and standard deviation of each group.
7. Plot group frequency distributions.
8. Set upper control limit (UCL).
9. Audit leadtimes greater than UCL.
10. Pinpoint worst cases.
11. Develop statistical smoothing techniques.
12. Establish a viable leadtime planning policy.
13. Communicate actual leadtimes to requestors.
14. Celebrate success with employees on the Materials Acquisition Assembly Line.

CONCLUSION

The challenge offered the materials manager is to develop his own leadtime management system. The effort is worthwhile because of many benefits. First, costs will be controlled and uncertainty reduced. Second, as with any type of system analysis, the materials manager's study of his own material acquisition process will give him greater and more detailed understanding of the existing system. Third, a leadtime management system offers a method for more intense coordination among base or plant level functional managers. Finally, a leadtime management system can assist in improving the morale of those personnel processing documents and property along the materials acquisition process assembly line.

By developing and using a leadtime management system, the base and plant level materials manager can improve both the certainty of leadtime estimates and the actual leadtime performance. When leadtime management joins the cost and quality control systems as a standard management system, only then can leadtime management become a key to materials management.

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HOW TO GET WHAT YOU WANT, WHEN YOU WANT IT

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ABSTRACT

For a short while now, I have been dealing with "stones weight," "fortnights," and the varying "pound sterling." To say the least, in an atmosphere where your rate of exchange varies from $1.55/pound to $1.98 per pound in a short period of time requires a certain amount of advanced planning. Overseas contracting does have some rather unique peculiarities; however, after having been involved in the procurement process on both sides of the Atlantic, I think many of the techniques involved are basically the same.

Perhaps the major difference in overseas contracting efforts is that it is more of a team concept. In addition, due to a somewhat slower life style, the planning and initial contract stage must be started much earlier. Here again, I think this should apply to Stateside contracting. One of our major contracting problems is that not enough thinking and planning is done at the start to fully describe and explain what we really want to buy. Many times we get exactly what we asked for only to find it is not what we really want. In contracting, the drawing board and pen are vastly superior to the written word. In like manner, the spoken word is worth nothing at all.

This paper deals with commonly occurring contracting problems that all of us face, in knowing what we want, but not being able to describe it; it costs too much; I need it now; and "who ordered this thing?"

The central part of the paper concerns procurement techniques that have been found useful and methods to avoid some pitfalls. The paper concludes with a recommended cookbook recipe for good contracts. This recipe is by no means all inclusive but serves only as a good guideline for a wide range of contract types.

The guiding theme of the paper is the absolute necessity to plan your <u>entire</u> contract effort well in advance and to <u>involve</u> all procurement resources available to you in a combined team effort.

ENHANCED PROCUREMENT PROCEDURES FOR PROCUREMENT OF
ELECTRONIC WARFARE (EW) EQUIPMENT

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ABSTRACT

This study will review the current Armed Services Procurement Regulations (ASPR) and Air Force Systems Command (AFSC) procurement guidelines that relate to rapid procurement of EW equipment. Various regulatory and policy guidelines will be reviewed as well as recent periodicals and other unpublished research projects that provide current government thinking on rapid procurement techniques.

Current procurement lead times will be contrasted to the expedited procedures set forth in Quick Reaction Capabilities (QRC) regulations. Four leading defense contractors of EW equipment have been offered an opportunity to provide an industry input to this study.

The current trend at HQ USAF does not permit easy approval of QRC procedures. Therefore, alternative procurement methods will be suggested. Of course, the alternative methods are less desirable than the QRC process and will require official sanction before they can be implemented. The study will conclude with recommendations concerning future procurement procedures.

HOW TO IMPROVE CONTRACTING PRODUCTIVITY BY MODELING THE CONTRACTING PROCESS

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ABSTRACT

Managing the contracting process involves three major concerns: (1) allocating human resources, (2) meeting time deadlines, and (3) maintaining contract quality control. As demands increase to produce more contracts in less time with fewer human resources, contract quality will suffer unless the productivity of the contracting process is improved. This paper proposes one way of systematically studying contracting productivity, where contracting is the process which produces a document called a contract. The central idea is that the contracting process can be modeled, much as many production processes have been modeled, and that through modeling, areas for improving productivity can be identified and the tradeoffs among resource allocations, time deadlines, and quality control made explicit. While the idea of modeling the contracting process is a general one, and there are many modeling techniques available, this paper presents one simplified example using Monte Carlo simulation to illustrate the approach. The paper concludes by discussing how such a productivity improvement research program could be established in practice, identifying some of the techniques available, and suggesting what some of the eventual benefits of such a program might be.

LOGISTICS INCENTIVES

STATISTICAL RISK ASSESSMENT IN STRUCTURING AND MANAGING THE LOGISTIC SUPPORT COST COMMITMENT

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I. INTRODUCTION

During the past few years, the management concept of "Design to Cost" (DTC) has been implemented with considerable success by the DoD. A variety of system and equipment acquisition programs have incorporated an average unit flyaway (rollaway, or sailaway) cost target in the development/production contract early in the development phase, in order to control program costs throughout the development and production processes. As experience in implementation of the DTC concept has accumulated, however, there has developed a widespread awareness of the need for broadening it to encompass not only development and production costs but also operating and support (O&S) costs. Indeed, DoD Directive 5000.28 [5:3] states that "as the ability to translate O&S costs elements into 'design to' requirements improves, Design to Cost goals may be extended into this area." It also states that, at a minimum, "the major operating and support cost factors shall have goals established in the form of measurable numbers (e.g., numbers of O&S personnel, reliability and maintainability factors, etc.) which can be monitored during test and evaluation as well as in operation." The Joint Logistics Commanders' Design to Cost Guide [4:23-24] also stresses the need for contractual O&S cost goals which are "design dependent, predictable, and verifiable." In addition, it emphasizes the need for formulating O&S cost goals in terms of dollars, stating that "in order to balance all the elements of production and operating and support costs with performance and schedule, ... it is necessary to convert the measures of reliability and maintainability, such as MTBF and MTTR, into expressions of cost."

The DoD has begun to experiment with several techniques designed to transmit DoD O&S cost goals to the Contractor. One such mechanism used by the Air Force in several recent procurements is the Logistic Support Cost Commitment (LSCC), sometimes referred to as a Support Cost Guarantee. The LSCC has three key elements:

1. A target logistic support cost (TLSC), defined in terms of a logistic support cost (LSC) model framework
2. A field verification test procedure, including computation of a "measured" logistic support cost (MLSC)
3. A contract remedy or price adjustment, which is a function of verification test results (particularly the MLSC).

Two procurements in which the LSCC has been incorporated are the AN/ARN-101 tactical LORAN, managed by the Air Force Electronics Systems Division (ESD) at Hanscom AFB, Mass., and the F-16 aircraft, managed by the Air Force Aeronautical Systems Division (ASD) at Wright-Patterson AFB, Ohio. In the case of the F-16, the LSCC is in effect at two levels. First, there exists a "system-level" TLSC, a target LSC with respect to the aggregate of 280 of the aircraft's line replaceable units (LRUs). The LSCC includes a multi-million dollar award fee provision with respect to this target but no negative incentive. Second, there exists a TLSC specifically with respect to three of the aircraft's high cost LRUs: the fire control radar, the electro-optical (E-O) display, and the E-O display electronics. The LSCC includes provisions for both positive and negative contract adjustments with respect to this latter TLSC.

This paper summarizes results of recent research into the statistical risks associated with structuring and managing the LSCC. Particular attention is paid to the impact of statistical risk on the interpretation of test results relative to the contractual target. The paper presents several critical insights into the statistical risk properties of the LSCC and discusses how these insights can be utilized in structuring future LSCCs. It demonstrates the importance of a clear and adequate assessment of these risks as a precondition to the effective use of contractual O&S cost targets by the DoD in its efforts to reduce system and equipment life cycle costs.

II. THE ROLE OF THE COST MODEL FRAMEWORK

The LSCC uses a simplified cost model framework to represent Government LSCs as a function of Contractor-controllable equipment logistics parameters in the manner recommended by the Joint Logistics Commanders' Design to Cost Guide [4:23-24]. Figure 1 reflects an LSC framework typical of those used in recent LSCC applications. (A list of model parameter definitions appears in Appendix A.) Such a cost model framework (CMF) is usually developed by program office or acquisition management staff personnel and provided to competing contractors as part of the LSCC provisions, ultimately becoming part of the negotiated contract. The CMF establishes a basis for formal communications between Contractor and Government regarding LSCs.

FIGURE 1. A TYPICAL LSC MODEL FRAMEWORK*

C_1 = cost of initial spare items

= (Cost of base repair pipeline spares) + (Cost of depot repair pipeline spares)

$$= (M)(\underline{STK})(UC) + [(PFFH)(UF)(QPA)(1 - \underline{RIP})(\underline{NRTS})/(\underline{MTBF})]\ (DRCT)(UC)$$

where STK is the minimum value of i such that

$$XBO(i,\ \lambda t) = \sum_{x>i} (x - i)\ P(x|\lambda t) \leq EBO,\ P(x|\lambda t) \text{ is Poisson, and}$$

$$\lambda t = \left(\frac{(PFFH)(UF)(QPA)(1 - \underline{RIP})}{(M)(\underline{MTBF})}\right) \left((\underline{RTS})(BRCT) + (\underline{NRTS})[(OSTCON)(1 - OS) + (OSTOS)(OS)]\right)$$

C_2 = cost of on-equipment maintenance

= (total mean number of failures) x (average on-equipment repair cost per failure)

$$= [(TFFH)(UF)(QPA)/\underline{MTBF}] \times [\underline{PAMH} + (\underline{RIP})(\underline{IMH}) + (1 - \underline{RIP})(\underline{RMH})] \times BLR$$

C_3 = cost of off-equipment maintenance

= (total mean number of off-equipment repairs) x (average cost per off-equipment repair)

$$= [(TFFH)(UF)(QPA)(1 - \underline{RIP})/\underline{MTBF}] \times [(\underline{RTS})(\underline{BMH})(BLR + BMR) + (\underline{NRTS})(\underline{DMH})(DLR + DMR)]$$

*Where possible, definitions (see Appendix A) and symbology appearing in this typical LSC model framework are identical to those used in the Air Force Logistic Command's LSC Model. This model is described in [3]. A further assessment of the model as a tool for comparison of competing systems, trade-off analysis, program cost and performance tracking, and trend evaluation can be found in [1].

The underlined parameters in Figure 1 (e.g., MTBF and NRTS) reflect hardware logistics characteristics over which the Contractor has a degree of control through his design engineering process. These are typically targeted by the Contractor in the equipment proposal. Subsequently, they are estimated or "measured" during a field verification test, which covers a period of from 3,000 to 6,000 hours of operation of the equipment in its field environment. Virtually all remaining model parameters (e.g., M = number of bases to which the equipment will be deployed) describe the environment in which the equipment will operate and be maint ned, and are supplied by the Government with t model framework.

The negotiated contract includes a target LSC (TLSC) which reflects the LSC impact of the various Contractor-targeted equipment logistics parameters. This target exists in addition to other contractual goals and targets such as a life goal on average unit flyaway cost. At completion of the field verification test, "measured" values of these parameters are inserted into the CMF in place of their corresponding Contractor-targeted values and the resulting cost value is called the measured LSC (MLSC). A positive or negative contract adjustment is made as a function of whether the Contractor meets or underruns his LSC target (MLSC $\leq$ TLSC) or overruns it (MLSC > TLSC).

III. CHARACTERIZING THE RISKS AND CONTROL PARAMETERS

The statistical risks underlying the LSCC can be completely described in terms of the following four quantities:

1. Statistical risk to the Contractor

2. Statistical risk to the Government

3. Length of the verification test period in total weapon system operating hours (=T)

4. An MLSC threshold above which a contract remedy is required.

The MLSC threshold is some given dollar amount larger than the TLSC. Let this quantity be called the remedy threshold, denoted by RT. It is convenient to be able to expre the remedy threshold in terms of some factor (>1) times the TLSC. Let the expression TF,

reflect this threshold factor. By this convention,

$$RT = TF \times TLSC. \qquad III.1$$

The development of the TLSC by the Contractor in his equipment proposal can be interpreted as his assertion that the underlying true population LSC value, MMLSC, to be estimated by the MLSC will be less than or equal to the TLSC, i.e.,

$$MMLSC \leq TLSC \qquad III.2$$

The LSCC also addresses the possibility that the Contractor's assertion may be false, i.e., that

$$MMLSC > TLSC. \qquad III.3$$

The basic decision rule incorporated in this LSCC is (1) to seek no contract remedies if the MLSC does not exceed the remedy threshold, i.e., if

$$MLSC \leq TF \times TLSC, \qquad III.4$$

and (2) to seek the remedy or negative adjustment if the threshold <u>is</u> exceeded, i.e., if

$$MLSC > TF \times TLSC. \qquad III.5$$

The interval from the TLSC to RT = TF x TLSC represents a margin of safety in the Contractor's favor.

The statistical risk to the Contractor under the LSCC is simply the probability that the Government will reject his equipment when, indeed, he has met or underrun his target. Let us call this probability α. In terms of the conceptual framework presented above, α is simply the probability of getting an MLSC value that suggests rejection of the Contractor's equipment when in reality, the underlying LSC value, MMLSC, which the MLSC is estimating, is less than or equal to his target, i.e.,

$$\alpha = Pr(MLSC > TF \times TLSC | MMLSC \leq TLSC). \qquad III.6$$

In order to develop an analogous expression for Government risk, we first define TLSC' to be the Government's "rejection target," that is, a specified value of MMLSC, <u>greater than the remedy threshold</u> RT = TF x TLSC, at which the Government wants to ensure a high probability of rejection. The statistical risk to the Government under the LSCC is defined to be the probability, henceforth called β, of getting an MLSC value that suggests acceptance of the Contractor's equipment when indeed, he has actually overrun his target to the extent that MMLSC = TLSC', i.e.,

$$\beta = Pr(MLSC < TF \times TLSC | MMLSC = TLSC'). \qquad III.7$$

We henceforth refer to α, β, T and TF as the "control parameters" of the LSCC.

IV. THE RISK ASSESSMENT MODEL

As part of the study described in this paper, a risk assessment model was developed which explicitly incorporates the mathematical relationships among the four control parameters defined above. The relationships indicate that a change in the value of one parameter cannot be achieved without a change in the value of at least one of the other three. For example, a change in test length (T), holding the threshold factor (TF) constant, results in changes in both Contractor risk (α) and Government risk (β). Alternatively, a decrease in Contractor risk, holding the threshold factor constant, can be achieved only at the expense of an increase in test length. Or if test length must be held constant but the threshold factor is allowed to vary, a decrease in Contractor risk can be achieved by increasing the threshold factor. However, this also results in an increase in Government risk.

Because of the complexity of the CMF used in the LSCC, the relationships among the control parameters are difficult to formulate precisely. This complexity can be overcome through efficient computer programming of the model, however. Such a set of programs can be used as a vehicle for explicit consideration of trade-offs among the four parameters. The example below illustrates the kinds of insights and information that it can provide.

V. EXAMPLE

Suppose that an LSCC is to be incorporated in the procurement of an item of avionics having an average unit production cost of \$40,000-\$60,000 and an MTBF ranging from 400 to 600 hours. Suppose that the Figure 1 CMF is used for the development of each bidder's TLSC and subsequent measurement of the MLSC in the case of the winning Contractor, henceforth called Contractor A. In particular, suppose that the Government-furnished program parameters and verification test parameters are as shown in Figure 2 and the equipment logistics parameter targets for Contractor A, along with Government rejection targets are as shown in Figure 3.

The flying hour values in Figure 2 represent official program office flying schedule projections, while the repair cycle times and labor/material rates have their origins in Air Force base and depot maintenance and supply accounting systems. The test length of 3,000 hours represents a figure negotiated between the program office and the item using command. The threshold factor of 1.25 was

developed through negotiation between Contractor A and the Government.

FIGURE 2. VALUES OF CMF PARAMETERS UNRELATED TO EQUIPMENT CHARACTERISTICS

PROGRAM PARAMETERS

PFFH	= 15,000 hrs./mo.	BLR	= \$11.70/hr.
TFFH	= 1,500,000 hrs.	BMR	= \$ 2.28/hr.
BRCT	= .13 mo.	DLR	= \$12.44/hr.
DRCT	= 1.84 mo.	DMR	= \$ 6.72/hr.

TEST PARAMETERS

T = 3,000 hrs.
TF = 1.25

Note: Refer to Appendix A for parameter definitions.

FIGURE 3. VALUES OF CMF EQUIPMENT-RELATED PARAMETERS

CONTRACTOR A TARGETS (TLSC = \$1,250,000)

UC = \$50,000
MTBF = 500 hrs.
UF = 1.0, QPA = 1.0

Repair Level and Man-Hour Parameters

	RIP	RTS	NRTS	PAMH	IMH	RMH	BMH	DMH
U. Bound	0.0	.99	.20	.50	0.0	2.0	9.0	10.0
Target	0.0	.90	.10	.25	0.0	1.0	5.0	10.0
L. Bound	0.0	.80	.01	.10	0.0	.10	1.0	10.0

GOVERNMENT REJECTION TARGETS (TLSC' = \$1,900,000)

Same as Contractor A except for MTBF = 325 hrs.

Contractor A's equipment item has an average unit production cost target (UC) of \$50,000, a target MTBF of 500 hours, and a TLSC of \$1,250,000 (see Figure 3). The remaining parameter targets corresponding to this TLSC .e fraction of in-place repairs = 0.0, fraction of base repairs = .90, etc. In addition to his parameter targets, Contractor A has provided his estimate of the range of values that his equipment parameters may ultimately assume in the form of upper and lower bounds. These ranges are required to develop a meaningful assessment of Contractor and Government statistical risks.

The cost overrun value at which the Government wants to guarantee a high probability of equipment rejection in this example is TLSC' = \$1,900,000. This "rejection target" is about 50% greater than Contractor A's target. It corresponds to repair level and manpower parameter targets identical to the Contractor's, but decremented MTBF target of 325 hours. In other words, the Government would like to guarantee rejection in the case where Contractor A achieves an MTBF of only 325 hours while meeting all his remaining parameter targets.

Note that both the target and bounds for the depot man-hour figure (DMH) are 10 hours in Figure 3. This is due to the exclusion of the parameter, depot man-hours, from the set of parameters to be verified because the relatively low equipment NRTS rate would result in an extremely small number of depot repairs during the verification test period and hence, a statistically inadequate sample upon which to base an estimate of actual DMH.

VI. RISK ASSESSMENT RESULTS

For these CMF parameter values and in particular a test period of 3,000 flying hours and a threshold factor of 1.25, the Contractor and Government statistical risks are reflected in Figure 4. The Contractor's probability of having his equipment rejected when he has actually met his TLSC ranges approximately from .23 to .32 with a most likely value of .28. The Government's probability of equipment acceptance when its rejection target has been met ranges from .26 to .35 with a most likely value of .32. The existence of a range of risks for each party, as opposed to a single point risk, is a distinctive property of the LSCC. Its cause is the relative complexity of the CMF used for development of the TLSC and MLSC. The size of each risk range is partially a function of the estimated ranges for the repair level and man-hour parameters appearing in Figure 3. However, sensitivity analyses with the risk assessment model have shown that the sizes of the risk ranges are relatively insensitive to minor revisions in estimates of the parameter ranges that might occur during negotiation of the LSCC terms and conditions.

FIGURE 4. RISK ASSESSMENT RESULTS (Representative Case)

Contractor Risk = Pr(Govt. Rejects Equipment When Contractor Target is Met) = α

$\alpha \approx .28, .23 \leq \alpha \leq .32$

Government Risk = Pr(Govt. Accepts Equipment When Govt. Rejection Target is Met) = β

$\beta \approx .32, .26 \leq \beta$

Hence, the existence of risk ranges, though it may make the LSCC risk properties slightly more

difficult to understand and interpret, does not constitute a serious weakness of the LSCC structure.

The size of the risks appearing in Figure 4 is another matter. These risks are high when viewed either in terms of their most likely values or their ranges, and would very likely be interpreted as unacceptable in a real-world setting. The reason for this is that eight parameters (MTBF, RIP, RTS, NRTS, PAMH, IMH, RMH, and BMH) are being verified simultaneously and the variabilities of the individual parameter estimates are combining through the CMF to produce a high variability in the MLSC. Since the concept of simultaneous verification of several logistics parameters is central to the application of LSCCs, the likelihood of high risks is an intrinsic property of the LSCC when it is defined with respect to a single equipment item.

Experience with the risk assessment model suggests that in many cases, steps can be taken to reduce these risks with a minimal dilution of verification objectives. Two approaches are described in Figure 5. The first is to reduce the number of parameters to be verified. Verifying only MTBF instead of all eight logistics parameters in our example reduces Contractor risk (most likely value) from .28 to .22 and Government risk from .32 to .24. A variety of related strategies exists. One, for example, consists of verifying all eight parameters but defining two separate MLSCs: one (say $MLSC_1$) with MTBF being held constant at its target and the remaining seven being estimated, and the other ($MLSC_2$) with just the opposite configuration, and then defining MLSC as the average of $MLSC_1$ and $MLSC_2$. This strategy reflects a small reduction in verification potential to achieve much more favorable risk characteristics.

FIGURE 5. RISK ASSESSMENT RESULTS
(Alternative Approaches)

REDUCING THE SET OF PARAMETERS TO BE VERIFIED

- Same as Representative Case except only MTBF is subject to verification and all remaining parameters are assumed to achieve Contractor targets

- Contractor Risk = $\alpha \approx .22(.28)$

- Government Risk = $\beta \approx .24(.32)$

INCREASING TEST LENGTH

- Same as Representative Case except T = 10,000 hrs. (3,000 hrs.)

- Contractor Risk = $\alpha \approx .19(.28)$

- Government Risk = $\beta \approx .20(.32)$

Figure 5 also reflects the impact of increased test length in the case in which all eight parameters are verified. It show that by increasing T from 3,000 hours to 10,000 hours, Contractor risk can be reduced from .28 to .19 and Government risk from .32 to .20. This result illustrates the general fact that because of certain statistical properties of the CMF, dramatic increases in test length tend not to bring about commensurate reduction in risks. If a further risk reduction is desired, other changes can be explored, e.g., a change in the threshold factor (TF), a redefinition of the Government's rejection target (TLSC'), or even minor changes in the CMF.

VII. AGGREGATION OVER SEVERAL ITEMS

A particularly notable property of the LSCC clarified by risk assessment model analyses is that statistical risks can be reduced by applying the LSCC to a group of items, in which case a single TLSC is developed for the aggregate of items instead of separate TLSCs for each individual item. Figure 6 illustrates this property. Suppose an LSCC is implemented with respect to the procurement of three items, all to be produced by the same contractor, and that the average unit costs and target MTBFs for the winning bidder again called Contractor A, are as shown (where it is assumed for purposes of illustration that the remaining eight parameter targets for all three items are identical to those used in the original single item example in Figure 3).

If a TLSC were defined for the first item only, the Contractor risk would be .28 (most likely value of range) and the Government risk, assuming a rejection target of TLSC' = 1.5 x TLSC (resulting, again, only from a decremented MTBF) would be .32.

FIGURE 6. AGGREGATION UNDER THE LSC COMMITMENT

AGGREGATION REDUCES STATISTICAL RISKS

- Item 1: UC = \$ 50,000, MTBF = 500 hrs.: $\alpha = .28$, β (1.5 x TLSC) = .32

- Item 2: UC = \$ 75,000, MTBF = 250 hrs.: $\alpha = .22$, β (1.5 x TLSC) = .26

- Item 3: UC = \$100,000, MTBF = 150 hrs.: $\alpha = .17$, β (1.5 x TLSC) = .21

- Items 1, 2, and 3 in Aggregate: $\alpha = .10$, β (1.5 x TLSC) = .10

Figure 6 shows similar results for Items 2 and 3, assuming individual targets and the same

threshold factor, TF = 1.25, in each case. The progressively lower risks result from an increasing ratio of test period length (again, 3,000 hours) to MTBF, which reflects the likelihood of more failures being verified and consequently, increasing statistical confidence.

Figure 6 indicates that by summing the targeted LSCs for the three items and defining the formal commitment TLSC in terms of this sum, a rather dramatic reduction of both Contractor and Government risks to .1 is achieved. The cause of this reduction is the existence of statistical independence of verification test data among items. This independence has a smoothing effect on the MLSC.

The property of reduced risk under aggregation is noteworthy and suggests that use of the LSCC should be given serious consideration as an LSC reducing mechanism in procurements where the possibility of cost aggregation exists. However, two caveats should be noted. The first deals with the passing down of LSCC provisions from the Prime Contractor to his subcontractors. Suppose an LSCC is implemented with respect to an aggregate of items under a prime contract and risk analyses indicate that the negotiated threshold factor and test length reflect acceptably low risks to both the Government and the Prime Contractor. Considerable caution should be used by the Prime if he passes down essentially the same form of LSCC provision on an item-by-item basis to his subs. If subcontract remedies or price adjustments are based on the same threshold factor and test length, subcontract statistical risks may be prohibitively high. The likelihood of this occurrence may call for the substantial modification of LSCC structure at the subcontract level, e.g., a provision for additional verification testing of certain items at the expense of the Prime Contractor.

The second caveat deals with the masking of bad reliability and maintainability performance of individual items. When an LSCC is implemented in the aggregate, it is possible that one or two items will have exceptionally high measured LSCs during the verification test, but the aggregate target will still be met due to the offsetting effect of low measured LSCs for the remaining items. From the point of view of cost, such an occurrence does not reflect a problem, since the Government's primary concern is with aggregate LSC and the LSCC has presumably shown whether the aggregate cost target has or has not been met.

But this possibility may reflect a serious problem from the point of view of total weapon system readiness, since the one or two poor performing items, while not causing prohibitively high aggregate LSC, may ultimately be prime causes of weapon system down time in the field. There are no simple solutions to this problem. One possible alternative is the use of a contractual target on readiness at the weapon system level in conjunction with an aggregate, LSCC. Such a set of dual macro targets, if they could be unambiguously defined, would have the effect of controlling aggregate costs of support resources utilized while preventing the logistics performance of any one item from getting too far out of line. The formulation of system level targets on readiness that functionally incorporate subsystem performance is not an easy task, however, and requires further research.

VIII. THE FUTURE ROLE OF RISK ASSESSMENT

The risk assessment procedures discussed in this paper provide the Government with a powerful new tool to reduce the life cycle costs of military hardware. They add considerable substance to the concept of the LSCC and their development has numerous implications for the structuring and management of the LSCC.

The risk assessment procedures can be used to develop LSCC structures that maximize Contractor incentive to reduce real Government incurred LSCs while maintaining statistical risks to Contractor and Government at acceptable levels. For example, the impact of alternative CMFs on the relationships among the control parameters (α, β, T and TF) can be assessed in a rigorous manner. This capability can pave the way for development of CMFs which adequately represent the costs of actual equipment demands for logistic support resources while reflecting (1) minimal risks to Contractor and Government, (2) a threshold factor (TF) value which is acceptable in the contract negotiating environment, and (3) a test length (T) value that is realistic vis-a-vis using command objectives and operating constraints. The procedures can also be used in this experimental mode to isolate those classes of equipment which, due to the nature of their demands on supply and maintenance resources, would be particularly well suited for use of the LSCC. For example, experimentation to date suggests that equipments exhibiting relatively lower unit costs or requiring fixed-length overhaul intervals tend to result in lower statistical risks.

Having developed an explicit relationship among the four control parameters of the LSCC, we can now make some significant observations regarding how these parameters should be set in a real-world contracting environment. It would be desirable to be able to determine values for all four parameters during development of the request for proposal (RFP) for a [illegible] included in it. This would permit extensive studies of trade-offs among the four parameters, by Government personnel. Furthermore, it would provide both Government and Contractor with time to study the LSCC statistical [illegible] characteristics prior to negotiation of detailed terms and conditions of the LSCC.

Such a prior determination of control parameter values cannot be made, however, because precise assessments cannot be generated until the Contractor's targets for all parameters to be verified are known. In other words, various risk properties of the LSCC naturally differ from one bidder to the next. Consequently, only preliminary estimates of risk characteristics based on Government assessment of industry capabilities and experimental runs of the risk assessment model can be undertaken prior to receipt of bidders' proposals. In view of this constraint, a possible scenario for determination of parameters is described as follows:

Step 1: An upper bound on α = Contractor risk is incorporated by the Government in the RFP as a guaranteed condition of the LSCC.

Step 2: Each bidder submits a TLSC with targets for parameters to be verified as part of his proposal and the Government selects a source for equipment development and production.

Step 3: Subsequent to contract award, the Government inserts the winning bidder's parameter targets and Government rejection targets into the risk assessment model and trades off test length (T), threshold factor (TF), and β = Government risk subject to the upper bound on α, until a set of control parameter values that minimizes expected LSCC costs to the Government is found.

This scenario provides an explicit limit on statistical risk to the Contractor well in advance of negotiation of detailed terms and conditions of the LSCC, while, at the same time, attempting to provide maximum flexibility to the Government in its search for a minimum expected cost position.

IX. CONCLUSIONS

The research summarized in this paper has led to several broad observations:

- The use of a simplified cost model framework as a basis for logistics targets and measurements provides a mechanism for focusing Contractor design efforts on equipment characteristics affecting failure rates and repair requirements commensurate with the relative impacts of these characteristics on LSCs. However, the framework must be developed with care to ensure that it summarizes these cost impacts accurately while simultaneously being simple enough to be interpreted without confusion in a contracting environment.

- Analytical techniques described in this paper can be used to assess trade-offs among alternative LSC Commitment model frameworks, risks, thresholds, and test lengths. Through this analysis, those LSC Commitment configurations that most effectively convey Government LSC reduction goals to the Contractor can be found.

The simultaneous verification of several logistics parameters in the operational environment called for by the LSC Commitment tends to result in either high statistical risks to Contractor and Government or unacceptably long field verification test periods. The technique of applying the LSC Commitment with respect to an aggregation of equipment items results in reduced risks, and hence may provide a workable solution to this problem. But the technique has the potential drawback of masking poor logistics performance of a small number of equipment items in the aggregation. While this attribute is not a matter of primary concern from the standpoint of aggregate LSC expenditures, it may contribute to reduced visibility of logistics performance impacts on weapon system readiness.

- The LSC Commitment is an innovative contracting technique. It embodies the appealing concept of a macro target to summarize aggregate costs and transmit multiple incentives to the Contractor. However, because it has been used in only a small number of contracts to date, the LSC Commitment's effectiveness as a contracting and management tool requires continued evaluation. Future applications should be on a selective and controlled basis.

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APPENDIX A
LSC MODEL PARAMETER DEFINITIONS

BLR - the base labor rate ($/man-hour) (G)*

BMH - the average number of man-hours to perform intermediate level (base shop) maintenance on a removed item including fault isolation, repair, and verification (C)

BMR - the base consumable material consumption rate (including minor items of supply such as nuts, washers, rags, etc., which are consumed during repair of the item) (G)

BRCT - the average base repair cycle time in months, i.e., the elapsed time for a RTS item from removal of the failed item until it is returned to base serviceable stock (G)

DLR - the depot labor rate ($/man-hour) (G)

DMH - the average number of man-hours to perform depot-level maintenance on a removed item including fault isolation, repair, and verification (C)

DMR - the depot consumable material consumption rate (analogous to BMR) (G)

DRCT - the average depot repair cycle time in months, i.e., the elapsed time for a NRTS item from removal of the failed item until it is made available to depot serviceable stock (G)

EBO - the maximum allowable expected number of unfulfilled demands for a given LRU at the base at any point in time (G)

IMH - the average number of man-hours to perform corrective maintenance of the item in place or on line including fault isolation, repair, and verification (C)

M - the number of operating locations (G)

MTBF - the mean time between failures in operating hours of the item in the operational environment (C)

NRTS - the fraction of removed items expected to be returned to depot for repair (= 1 - RTS) (C)

OS - the fraction of the total force deployed to overseas location (G)

OSTCON - the average order and shipping time within the CONUS (G)

OSTOS - the average order and shipping time to overseas locations (G)

PAMH - the average number of man-hours expended in place on the complete system for preparation and access of the item; for example, jacking, unbuttoning, removal of other units, and hookup of support equipment (C)

PFFH - the peak force flying hours, i.e., the expected total fleet flying hours for one month during the peak usage period (G)

QPA - the quantity of like items within the parent system, i.e., "quantity per application" (C)

RIP - the fraction of item failures which can be repaired in place or on line (C)

RMH - the average number of man-hours to isolate a fault, remove and replace the item, and verify restoration of the system to operational status (C)

RTS - the fraction of removed items expected to be repaired at the base (= 1 - NRTS) (C)

STK - the stock level of the item at each base (M)

TFFH - the expected total force flying hours over the program inventory usage period (the projected life of the item) (G)

UC - the negotiated unit cost of a spare item as of the end of the verification test (C)

UF - the ratio of operating hours to flying hours for the item (C)

XBO - expected number of backorders of the item at a given base as a function of the stock level, i, and the mean rate of demands, λt, for the item (M)

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*Note: G - supplied by the Government
C - supplied by the Contractor
M - computed by the model

TRAINING DEVELOPMENTS: A MEANS OF INFLUENCING LIFE CYCLE COSTS*

Major Troy V. Caver, United States Army

ABSTRACT

STUDY PROJECT GOALS

To determine if training development can be considered along with hardware developments, in the system approach, for trade-off considerations for achieving lower life cycle costs and if so, how?

STUDY REPORT ABSTRACT

This report examines new training concepts developed throughout DoD over the past decade. The concepts that show promise for reducing life cycle costs are considered for trade-offs with hardware developments. The process of trade-off considerations is treated with a marginal cost-marginal benefit analysis (put the investment where it provides the biggest return). The writer then conducts a sensitivity analysis on parameters affected by training using a computer model to determine a trend in life cycle costs/savings. The writer concludes that many benefits can be derived by investing more in the training subsystem, in some cases, even at the cost of the hardware subsystem. These investments appear to be best placed in training and technical documentation or in job performance aids. He concludes that not only should this type investment reduce the life cycle cost but also provide job enrichment, higher operational availability, fewer maintenance personnel requirements, fewer training course requirements and other savings.
The implication of the study is that Project Management personnel concentrate on the hardware aspects of a developing system while training developments provide a greater return on the later investment and provides expectations of greater user satisfaction.

SUBJECT DESCRIPTORS

Training Developments
Technical Documentation
Job Performance Aids
Life Cycle Costs
Life Cycle Savings
Life Cycle Cost Models
Trade-Off Analysis

ABOUT THE AUTHOR

Major Troy V. Caver, US Army, is a Professional Engineer (Industrial), and has been interested in military hardware procurement and project management since attending the US Army Guided Missile Systems Officers course in 1968. He is a graduate of Henderson College in Arkansas (BS), University of Texas at El Paso (MSEE), the Command and General Staff College, the Armed Forces Staff College and the Defense Systems Management College, 'Project Manager's course' where this research study received the Commandant's distinguished award. This study was also selected as the US presentation to the Army Subgroup of the EURO/NATO Training Conference in Rome, Italy, in October 1977. He has six years of combat developments experience and additionally has served in operational units in Germany, Korea and as an Infantry and Field Artillery battalion advisor in Vietnam. He holds the Air Medal and Bronze Star with "V".

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*The complete 40 page study with more illustrations is available from Defense Logistics Studies Information exchange, DLSIE, ADA 045447 (AUTOVON 687-2240).

TRAINING DEVELOPMENTS: A MEANS OF INFLUENCING LIFE CYCLE COSTS*

Major Troy V. Caver, United States Army

EXECUTIVE SUMMARY

This study examines the benefits of recent Training Developments which are the results of integrating technical documentation and training techniques into a composite package. It also examines the results of Training Development studies conducted in all three US Services. It includes insights into the problems of achieving expected operational availability, maintainability, and lower Life Cycle Costs for new systems. The maintenance documentation concepts are examined illustrating the interrelationships of technical and training documentation with systems maintainability. The implications of using documentation concepts tailored for specific equipment type were investigated with the expected results recorded herein. Representative findings from the studies, tests, and experiments examined were used as computer data changes to a life cycle cost model with the computed results included in this report. These results were examined in light of recent DoD guidance to reduce Life Cycle Costs. It is concluded that the proper selection of promising training development concepts such as technical and training documentation will reduce life cycle costs and increase operational availability. Other more specific expectations are reduced personnel requirements, reductions in training time, decreased mean time to repair, fewer job specialties, reduction in spare parts usage, greater user satisfaction, and a more usable support package for foreign military sales.

It is further concluded that an overall systems effectiveness approach is required to give sufficient emphasis to training and support and insure project managers plan and contractually support the selection and development of the effective materials.

It is also concluded that revision of existing technical and training documentation may be a viable alternative to upgrading system performance and may be more cost effective than the customary hardware modifications of Product Improvement Programs (PIP).

The implication of the study is that present practices emphasize inherent hardware reliability and availability values while ignoring enhancement through improved training developments, a relatively simple means of receiving greater payoffs and increased user satisfaction while reducing life cycle costs.

INTRODUCTION

The job of maintaining a military force in a high state of readiness falls on the military commander. On the modern battlefield he is going to be equipped with sophisticated weapons and support equipment more complex than ever before. He has a major task of maintaining those weapons in a high state of readiness and to employ them in their mission whenever required to enter the battle. However, for years reports from users throughout the world have expressed concern and great difficulty in maintaining readiness conditions required. Many factors have been given as contributing causes such as lack of repair parts, high equipment failure rates, long times to repair, and inadequately trained maintenance personnel. Our servicemen and the country deserve equipment that once employed in battle can be expected to remain operational for the duration of the mission. Any system found to be nonoperable should be expected to be brought back to an operable condition in the minimum amount of time.

In a statement to the 94th Congress Second Session 3 Feb 1976 concerning DoD Research, Development, Test and Evaluation Program, Dr. Malcolm Currie stated:

"Since reliability, maintainability, and direct personnel costs influence operating and support costs, the DSARC has been imposing more stringent requirements for reporting actual field reliability and maintainability achievements and related support costs throughout the life of each program. This action will focus increased management attention on these elements of life cycle costs...."

*The complete 40 page study with more illustrations is available from Defense Logistics Studies Information Exchange, DLSIE, 704 046447 (AUTOVON 687-2240).

Lieutenant General George Sammet, Jr, Deputy Commanding General for Materiel Development, Army Materiel Development and Readiness Command, speaking at the American Defense Preparedness Association Tank Automotive Division Meeting in Monterey, California, 17 Nov 76 stated:

"Along with good maintenance is good technical data. If you are going to tune up your Ford you can't use a Jaguar manual to tell you how to do it. Using some of our manuals in the past was about like using a Jaguar manual to fix a Ford. Our old manuals were difficult to read, or there were no illustrations, or the illustrations were all wrong -- or at least wrongly placed in the manual. Some are still that way. But we are correcting this situation. We have to, if we are truly going to have equipment readiness."

Later he also stated:

"You can't put reliability in a vehicle after it's in the field. ...Reliability has to be built into a vehicle, and it's not going to get there by accident.

The same goes for Tech (technical) Manuals. They don't write themselves, yet manuals are as much a part of readiness as the mechanics tool kit...."

Also, while discussing support cost and Design to Unit Production Cost (DTUPC) he stated:

"Our critics argue that we should have been talking DTUPC and life cycle costing all the time. Since the life cycle cost is a lot tougher number to predict, we did push it into the background. Well, its time has come -- as they say on TV -- to get the whole package under a life cycle cost figure."

Over the past ten years, DoD has put much emphasis on improving the maintenance of the hardware by emphasizing reliability and maintainability as design criteria and the development of automatic and built-in test equipment. Very little attention, however, has gone into improving the maintenance information. The conventional technical manual system has existed without change for decades. Some gradual improvement has occurred but there has been no innovative thrust to improve the effectiveness of the people portion of our maintenance system. Also, as stated by Dr. Currie later in his referenced presentation, approximately 25% of all military personnel are employed in full time maintenance service. This does not include operators of trucks, tanks, guns, etc. If we consider the individual cost at $20,000 per man year (a low estimate) this represents $10 billion per year (this figure varies with total DoD strength currently 2.1M). If we then inject training costs, the DoD maintenance personnel support is easily in excess of $12.4 billion per year (1:50). The primary purpose for stating these facts is to put emphasis on the publications, training and personnel systems -- three of the many disintegrated (3) elements, reference Figure 1, of systems under development, each of which should integrate and improve system effectiveness by better training developments. Within the DoD community many experiments and demonstrations have shown that improvements to technical manuals and other new ways of presenting information may enable technicians to perform faster and more accurately, and with less training. These techniques have the potential of reducing the cost of maintenance and maintenance support (training) by 25-50% and at the same time improve the equipment availability. Two studies conducted for DoD elements in recent years were relied on heavily for this paper (1,2). Each of them reviewed and reported the many techniques and concepts used in improving training and maintenance. This paper will present the results of many of these examinations, discuss the applications and recommend several steps that DoD should take in implementing the results.

PURPOSE OF THIS STUDY PROJECT

It is the purpose of this paper to examine the the results of studies and experiments concerning new training development concepts (Section III) and to consider the influence on System Life Cycle Costs when applying these new concepts.

SPECIAL GOALS OF THIS PAPER

The goal of this paper is to answer the following question: Can training and technical documentation developments for achieving lower life cycle costs and if so, how?

SIGNIFICANCE OF THE STUDY

Many Department of Defense Directives and Instructions have been published stating Life Cycle Cost will be used as a constraint in System Acquisition. Other documents have stated the importance of user involvement. However, the primary emphasis of program managers and the system acquisition process continues to be <u>hardware</u> development and acquisition. While it

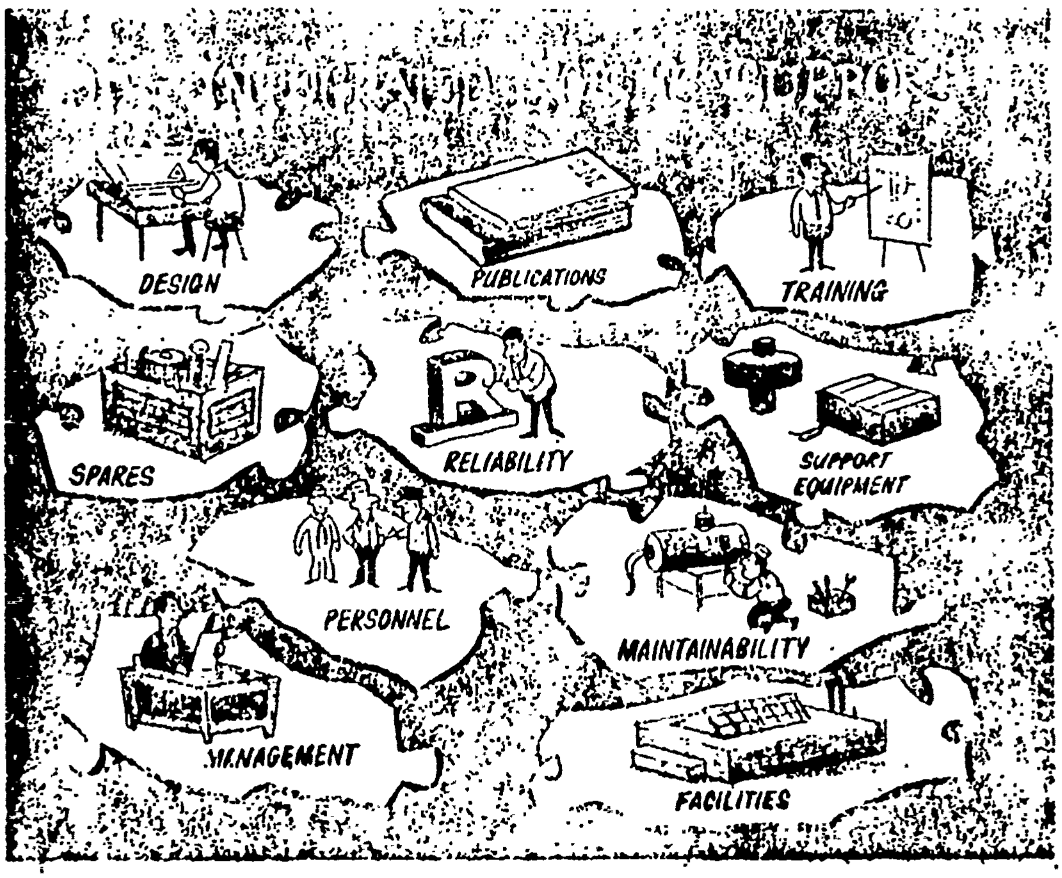

DESIGN
PUBLICATIONS
TRAINING
SPARES
RELIABILITY
SUPPORT EQUIPMENT
PERSONNEL
MAINTAINABILITY
MANAGEMENT
FACILITIES

Figure 1

is obvious that the primary element of the system initially is the hardware, and the early concern is in hardware development, it is not at all clear to this writer why the 'hardware fascination' continues throughout the acquisition process at the expense of the other system elements. If the many results of this study are recognized by DoD policy makers as worthwhile, the 'hardware acquisition process' will become the 'system acquisition process' in fact and not just in print. The benefits of such a change are obvious as hardware is only one of the many subsystems of the total system.

TRAINING DEVELOPMENTS AND OTHER RELATED SUPPORT DEFINITIONS

This section is to examine the meaning of training developments and related terms such as Job Performance Aids, technical data, and maintainability as used in this study.

TRAINING DEVELOPMENT

Training development as evolving throughout DoD (4:33) integrates technical documentation and training into a composite package which provides a reference state of all information needed to operate and maintain an equipment system. The technical documentation contains fully detailed, illustrated instructions which enable novice technicians to perform complex tasks with little or no training. The training materials consist of self study lessons which teach the preliminary skills necessary to use the documentation in operating and maintaining the equipment.

JOB PERFORMANCE AIDS

Job Performance Aids may be booklets or viewing devices which present step-by-step procedures with simple illustrations supported by easy to read text. They present the soldier with technical data in an illustrated, easy-to-read, step-by-step format supported by a training package which integrates the necessary material to teach critical tasks, frequently recurring tasks, and procedures relative to troubleshooting, safety, and emergencies. Key features of the new training development concepts are that (4:34):

- Development is based on an analysis of job and task requirements.
- Material is developed with the target audience and work conditions in mind.
- Technical data is presented in job sequence and organized for accessibility.
- Training and Technical Documentation are integrated.
- Technical manuals and training packages are verified by users under realistic conditions prior to acceptance.

Man's limitations and capabilities must be considered early in the hardware design and then personnel must be trained to the skill level required to operate, maintain, and support systems and equipment for ultimate effectiveness. They can do this only with proper technical data.

TECHNICAL DATA

Technical data provides the link between the man and the machine, the maintenance technician and the part, the driver and his tank. Technical data are written instructions such as drawings; operating, maintenance, and modification manuals, specifications, inspection test, and calibration procedures; and computer programs required to guide people performing operations and support tasks. It is difficult and impractical to maintain or operate much of the complex equipment now being produced without clear and simple written guidance. Thus the scheduling of technical data developments and distribution must mesh with equipment production schedules.

MAINTAINABILITY

Maintainability is a design characteristic which is expressed as the probability that an item will be retained in, or restored to, a specified condition within a given time period when maintenance action is performed. A parameter often used as an expression of maintainability is mean time to repair (MTTR).

A REMINDER

Maintainability is the <u>ability</u> of the item to be maintained whereas <u>maintenance</u> is a series of actions to restore or retain the item in the specified condition.

The maintainability characteristic of hardware dominates the number and types of trained personnel, tools, equipment, spare parts, and technical data for support of the equipment in an operational environment.

RESULTS OF STUDIES EXAMINING NEW CONCEPTS IN TRAINING AND DOCUMENTATION

This section presents the results of the many studies, tests, and experiments conducted to develop improvements in the military training and technical documentation.

There have been approximately eighty 'new concepts' designed or developed to make improvements on the performance of the personnel, primarily through improved manuals (2:12). Twenty-five research reports on some 30 new concepts report improvements in job performance or reduction of training time when manuals incorporating the new concepts were used. These reports were examined with the following two questions in mind:

1. How are the research results converted into lowering the cost of ownership?

2. What are the fundamental processes that make these new concepts so effective?

The examinations revealed that improvements must come from one of these:

1. Reduced training time.

2. Reduced number of personnel required to do the job. (Increased proficiency of individual men.)

3. Reduced errors (reduction of false removals improved by increased proficiency).

The assumptions common to the new concepts are that experts can analyze the equipment, determine what should be done to it in every possible situation, and record this in technical manuals so that even a novice can use it to perform the task correct . Using the new kinds of documentation, personnel with half as much training as groups using standard technical manuals, were able to correct three times as many malfunctions per unit time in a major radar system (2:10). All the concepts are directed at telling the man <u>what</u> to do instead of teaching him about the system details and training in what is basically design engineering information. It emphasizes <u>training</u> and not <u>teaching</u>. The new types of documentations provide a more intelligible product.

While one would assume that the current maintenance documentation is suitable, it rarely is. In analyzing the maintenance actions for the doppler radar system of the C-141, the Air Force found that the isolation and repair of one malfunction required reference to 165 pages of 8 documents (2:10).

In <u>all</u> of the experiments and field tests, inexperienced technicians performed better with fully proceduralized aids than with conventional documentation. Often, particularly when troubleshooting, the inexperienced technicians, even those who had attended the prescribed school, were unable to perform at all using conventional manuals. However, they were able to perform with minimal errors using the aids and their time to repair approached the time experienced technicians required when the latter used either conventional or experimental documentation.

To summarize some key findings of the studies:

- Repair time was reduced by up to 33 percent, with 80 percent fewer errors (BFIC) (2:13).

- As much as forty-two percent more malfunctions were found in 41 percent less time (MAINTRAIN) (2:12).

- Diagnosis time fell by as much as 67 percent (British Algoritthm) (2:13).

- Training time was reduced as much as 60 percent for troubleshooting tasks and up to 100 percent for non-troubleshooting (1:35).

- Inexperienced technicians using Job Performance Aids performed better than experienced technicians using traditional-type technical manuals (Non-Troubleshooting JPAs) (2:13).

CONSIDERATIONS OF APPLYING THESE CONCEPTS TO REDUCE LIFE CYCLE COSTS

This section examines the effects of the total systems life cycle costs when the study results are applied. For the maximum savings to be realized, incorporation of these new training concepts must be planned for as early in a systems development as possible.

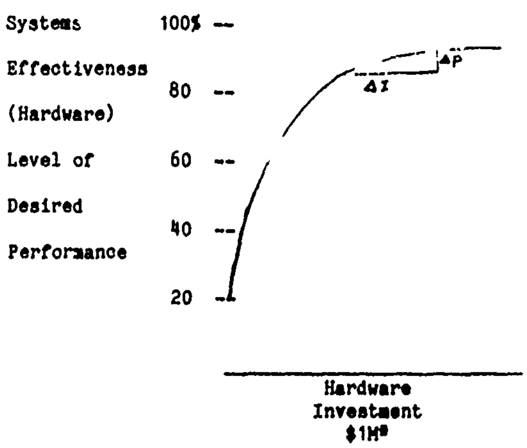
Many Program Managers will undoubtedly feel that training and logistic support are either minor elements of their program or someone else's primary responsibility. For them the following is provided:

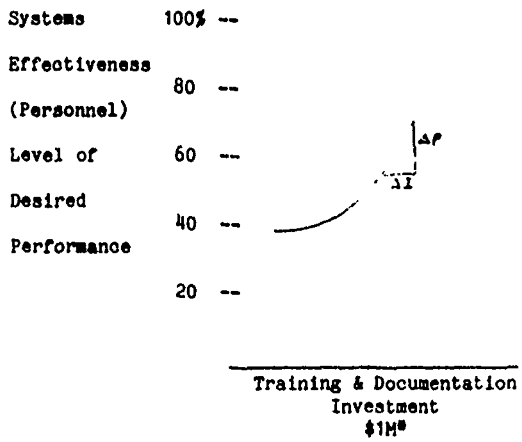
QUOTE FROM DESIGN TO COST POLICY IN THE ARMY MATERIAL COMMAND GUIDE, DEC 74 AND INDORSED ON 3 JUL 74 IN A SECRETARY OF THE ARMY MEMORANDUM TO THE CHIEF OF STAFF, US ARMY. SUBJECT: DESIGN TO COST

"Our ultimate objective is to minimize the total life cycle cost of ownership of a weapons system.... potential cost/performance trade offs and engineering changes must be evaluated in terms of their impact upon the overall cost of ownership of the system and appropriate weight should be given to this factor during source selection evaluation. Higher acquisition costs are acceptable provided that the additional investment will be amortized in a reasonable period of time through lower operating costs. However, designers should not be permitted to lower hardware acquisition costs to meet a design-to-cost goal if it would result in an uneconomical increase in operating and maintenance costs."

The systems of the future will be required to follow a design to cost philosophy. As human resources are a significant part of the life cycle costs of a system, to demand that systems be designed to human quality and quantity resource constraints from the very beginning is not only reasonable but necessary. The charts on Figure 2 show growth curves that can be expected in developing hardware and documentation (6:23).

FIGURE 2





*Note the scale of the two curves is not the same. A $100K investment in training and documentation could be expected to provide considerably more performance increase in system effectiveness than the same investment in hardware.

Most system acquisition programs are constrained by dollars, schedule, and performance. As money is invested over time, the performance parameters grow. Characteristically the hardware performance growth curve reaches a level where very little growth is realized even with extreme investments. The marginal return on the investment is very low. This portion of the curve is usually reached in the Full Scale Engineering Development Phase. Also, during this phase the technical documentation and the training aids must be developed and demonstrated. The management approach to getting the greatest life cycle cost benefit should be to invest the money in the portion of the program to provide the greatest marginal pay off, i.e., the greatest incremental return for the incremental investment. If improved training aids or technical documentation provide a greater expected LCC savings with a $1M investment than the same $1M investment in hardware reliability or maintainability improvement, then the investment should go into training aids and documentation.

Using a Life Cycle Cost model accessible by computer, this writer used the results of some of the earlier studies to determine expected savings. The model was exercised using a hypothetical but realistic electronic system under development. All inputs were held constant except those treated as variables for this examination. Base case was:

a. Number of job skills (base = 4)

FIGURE 3

ANALYSIS OF SYSTEM COST PARAMETERS AS
AFFECTED BY MAINTENANCE TRAINING VARIATIONS
USING THE GENERALIZED EQUIPMENT MAINTENANCE MODEL

	BASE	ALT 1	ALT 2	ALT 3	ALT 4	ALT 5	ALT 6
Job Skills	4	4	2	2	4	4	4
Probability Removing False Part	30%	30%	30%	10%	10%	10%	10%
Training Time Factor	1.0	1	1	.5	.5	.5	.5
Retrain Cycle	2.5 year	2.5	2.5	5	5	5	5
MTTR Factor	1.0	90%	90%	90%	90%	80%	70%
Cost of Selected Outputs (000)							
R&D	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Test Equipment	79.	71.	71.	71.	71.	63.	55.
Manpower	27,004	24,205	4,762	4,762	24,205	21,604	18,903
Training	15,144	6,785	4,702	2,351	3,393	3,029	2,650
Resulting Total LCC	70,183	59,010	37,484	35,133	55,617	52,645	4[illegible],558
Operational Availability	.9757	.9740	.9740	.9749	.9740	.9749	.9759

b. Probability of false maintenance diagnostic (4:33) (30%)

c. Training time/cost (20 wks/$20K for Job Skill 1, $30K for Job Skill 2)

d. Retraining cycle (2-1/2 yr)

e. Mean time to repair (MTTR) (varied with task) (used a factor of 1.0)

The study results used were:

a. Reduce MTTR 10%

b. Cut job skill requirements 50%

c. Reduce training time by 50%

d. Reduce false maintenance actions (parts replacements)

e. Examine a 5 year period between training

The model was exercised after changing each variable. The results are summarized in Figure 3. It is recognized that this exercise has been limited to a single model, however, the manpower and Life Cycle Cost reductions are so significant the results demand we can no longer afford to ignore the personnel subsystem.

The results indicate that a 10% reduction in mean time to repair (MTTR):

a. Reduced the test equipment cost by 10%

b. Reduced the manpower cost by 10%

c. Reduced the training costs by 50%

d. Reduced the Total Life Cycle Costs by 15.9%

A 50% reduction in the number of job skills further:

a. Reduced manpower costs an additional 80%

b. Reduced training costs an additional 30%

c. Reduced the Total Life Cycle Costs an additional 36.5%

A lowering of the false part removal from 30% to 10% and reducing training time by 50% further:

a. Reduced training costs an additional 50%

b. Reduced Life Cycle Costs an additional 6.3%

With all other parameters held steady, the MTTR was varied from 90% to 80%to 70% resulting in:

a. Reductions in test equipment cost by 11.27% and 12.7% respectively

b. Reductions in manpower costs by 10.7% and 12.5% respectively

c. Reductions of training costs by 10.7% and 10.5% respectively

d. Reductions of Life Cycle Cost by 5.34% and 5.8% respectively

In addition to the cost savings available by improving training and technical documentation, other benefits can be postulated:

- Job enrichment, hence higher expected reenlistment rate (7:21)

- Fewer errors in the contractor produced documentation

- More utilization of men now in supervisory positions (presently 71% of inexperienced labor observes and assists) (2:48)

- Fewer personnel moves as average stay on station for first termer is longer

- Technicians leaving service should be better trained for production in civilian economy (2:47)

- Improve reliability and operational readiness time

- Reduce unscheduled maintenance manpower

Although a cost savings can be shown, the new techniques will certainly meet with opposition. One objection to acquiring documents with the new concepts has been that they cost more than conventional documentation and that project managers faced with competing requirements resist their adoption. If the cost savings potential is even a small fraction of what is claimed by proponents, the initial cost should not be an overriding factor. A budget quotation submitted to AFLC in 1971 for completion of flight line JPAs for the C-141 was $1,300,000 with troubleshooting aids and $800,000 without. McDonnell-Douglas reportedly estimated that JPAs for the F-15 would cost $45 million versus $35 million for conventional documentation (2:50).

Most estimates indicate the cost at 100% to 125% of conventional documentation. In at least one case, cost estimates were less than the estimates for conventional manuals (2:50).

If new documents or JPAs were widely adopted, the production costs would probably come down due to the contractor learning and production techniques. Current JPA estimates from contractors accustomed to producing conventional manuals are probably inflated because of uncertainty. The industrial base for this kind of product would expand although fortunately there are currently at least a half dozen contractors who have demonstrated capability in this area.

CONCLUSIONS

The user is the program manager's customer. The whole purpose of system development or acquisition is to satisfy the user's need.

The service users have emphasized the need for technical and training documentation written at a lower reading level. The many studies conducted over the past two decades provide a means of satisfying this need and at the same time, reduce the manpower burden while improving the overall systems effectiveness.

A major problem is expected in implementing these study results. The institutional procedures don't change quickly. As long as Project/Program Managers emphasize Unit Production Cost at the expense of Life Cycle Cost the 'hardware fascination' will continue. The effect of the personnel subsystem must be considered as the imperfect subsystem it is. Hardware design parameters should be modified upward accordingly to allow for the degradation due to imperfect personnel and yet meet the operational requirements as stated in the requirements document.

Life Cycle Costs are being emphasized in DoD 5000.28 and other DoD instructions, however, most implementers have difficulty getting a handle on the operations and support costs. The use of models such as the one used to support this study are available in each service (9). They can provide sufficient data to support trade-off decisions in design, support equipment, manpower, and other resource limiting areas. To successfully use such models, information such as maintenance concepts, required operational and maintenance crews, types of maintenance tasks and the operational and logistic mission profile must be developed as inputs. In so doing the models will aid in design decisions (10). The Life Cycle Costs developed by this analysis indicates that although absolute costs may not be available, relative merit can be determined by examining trade-offs, and forcing the contractor to concentrate on the system cost drivers.

RECOMMENDATIONS

(1) That DoD direct each service to examine the possible life cycle cost savings, to each system undergoing Research and Development, as a result of using the documentation and training concepts developed by referenced studies and to implement those showing sufficient cost savings.

(2) Realizing that documentation, training aids, and devices must be developed as components of each system, this writer recommends:

(a) Invest the Research and Development dollars in the areas where the expected marginal return is greatest. This requires acknowledging that the investment may legitimately be applied to improving a subsystem other than the hardware.

(b) That each new requirement document be examined for satisfaction of its requirement by the following priority methods:

- New Job Performance Aids on existing equipment
- Product Improvement to existing equipment
- New System development

(c) That DoD schools dealing with systems acquisition take a more responsible role in teaching the development and contracting for improvement of high cost subsystems (other than hardware) such as personnel and logistic support. Also that the DoD schools be charged with assessing recommended methods to obtain Life Cycle Cost Savings and distribute promising methods to PM offices in each service.

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DESIGNING FOR LOGISTICS
AN INCENTIVE AWARD FEE APPROACH

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Captain Paul W. Gross, Jr.
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INTRODUCTION

The conceptualization, design, development, production, and deployment of a major weapon system constitute the five phases of the major systems acquisition cycle. This cycle is initiated with the approval of a mission need and is complete when the weapon system has been phased out of the operational inventory. Over the past several years the Defense Department has shown concern for the increased total life cycle costs (LCC) of major weapon systems. In an attempt to lower these costs, the acquisition cycle has been subject to many new innovations. One of the most significant changes has been that of increased emphasis of logistics support concerns during the early stages of the acquisition cycle. This has been accomplished by attempting to introduce logistics support criteria in the design phase of the acquisition cycle. The complexities of this phase of the acquisition cycle, the lack of experienced logisticians in the design discipline, the inability to correlate design decisions to logistics support requirements, and the lack of available and acceptable techniques for integrating logistics as a criteria for System Program Office (SPO) decision making are all important factors that have contributed to the difficulty of this task. This paper discusses the issues surrounding these factors, describes an approach that was used in a major Air Force weapons system acquisition, and summarizes some of the current issues that need to be addressed to further improve the use of logistics support criteria during the design phase of a major system acquisition

BACKGROUND

LCC another dimension of these criteria, logistics support, has received much more emphasis. Numerous weapons systems and subsystems have recently used an average unit flyaway cost target during the development and production phase of the program as a contract technique to control program costs. The concept of design-to-cost (DTC) was introduced to increase the visibility of rigorous cost goals. DTC is defined in Department of Defense (DOD) Directive 5000.28(5) as "a management concept wherein rigorous cost goals are established during development and the control of system costs (acquisition, operating, and support) to these goals is achieved by practical tradeoffs between operational capability, performance, cost, and schedule." To establish adequate DTC goals and to develop management criteria for making program decisions, it became apparent that not only were development and production costs important but there was a need in Defense acquisition to manage the operational and support (O&S) costs of a weapon system. This required management to introduce O&S cost factors into the design analysis. Since the design of major weapons systems is generally accomplished by contractors, it became necessary to develop methods that would permit the O&S cost factors to be stated in measurable numbers and terms appropriate for contracts. Such factors as reliability, maintainability, producibility, and human factors (man/machine interface) needed to be specified in measurable terms and placed in the early acquisition contracts as manageable goals. Also, with management's desire to emphasize LCC, these parameters had to be constructed in terms of dollars. Another reason for stating these design support goals in dollar terms was that other program parameters such as performance and schedule impacts were often stated in terms of program dollars. In order to establish design system operational and support cost goals, there was a need to state reliability, maintainability and producibility factors, in terms of design standards. Quantifiable standards of these factors for existing designs are difficult to identify and relate to new system designs. Past reliability and maintainability data from the operational environment has proven to be difficult at best to use for establishing goals during new design efforts. The use of engineering analysis and similarity to other systems have been used to establish these design guidelines in a few recent procurements.

Two contractual mechanisms for emphasizing the reduction of O&S costs are now being selectively used. These include the Reliability Improvement Warranty (RIW) and the Logistics Support Cost Commitment (LSCC). The LSCC is also referred to as the Support Cost Guarantee. The LSCC techniques involve establishing Target Logistics Support Costs (TLSC) in terms of a cost model that predicts logistics costs based on logistics factors. These TLSC's must be measurable and [illegible] table [illegible] field test environment where Measured [illegible]

Support Costs (MLSC) can be produced. To incentivise this mechanism, a contract price adjustment based on the comparison of the TLSC and the MLSC during the verification test must be provided.

The RIW is a contractual agreement under which the contractor is required to assume responsibility for all repair of an item over a given period of time at a prenegotiated fixed price. RIW also provides for increased profits if increased equipment reliability is demonstrated. Engineering changes are encouraged to reduce future operation and support costs. An additional incentive to design in higher reliability is provided when the RIW is part of the development/production contract.

The RIW and LSCC are being used in several major system acquisitions. Management is employing these techniques with a great deal of caution since their usefulness has not been completely evaluated. Some of the concerns of the Air Force with the use of RIW are: funding, equipment performance, measurement, engineering changes, and transition to organic support. The LSCC technique is more complex than the RIW to implement and administer. Its dependence on a cost model framework that must be tailored to the specific system design characteristics assumes a degree of stability in the design once the technique is initiated. The requirement for a field test verification may cause delays in obtaining useful results. These and other issues must be evaluated before this technique's usefulness will be completely appreciated. RIW is limited in application to a small, select group of equipment whereas the LSCC technique can, if proper tailoring is accomplished, be applied to total system acquisitions. To increase the role of logistics support as a major program criteria early in the acquisition cycle, the above techniques need further verification, improvement, and additional techniques need to be developed. To accomplish this several areas must be given careful consideration. These include: greater understanding of logistics support and its relation to design analysis; increased integration of design and logistics engineering activities; increased use, evaluation, and improvement of such techniques as RIW and LSCC; increased integration of logistics concerns in the program management office; and improved feedback of operational data on specific designs. The remaining portion of this paper will discuss each of these areas as they relate to a recent major system acquisition experience.

LOGISTICS SUPPORT CONSIDERATIONS IN DESIGN

Logistics support as it relates to a system (weapon system) can be described as the test and support equipment, consumables spares and repair parts, personnel and training, transportation and handling, facilities, and technical data necessary to successfully operate the system. In many cases the system, which consists of both the prime mission equipment and the associated logistics support, is designed as the prime mission equipment alone without due concern for the associated logistics support. Cost-effective systems cannot be developed without effectively including logistics support considerations throughout the entire system acquisition cycle. Particularly during the initial stages of design and development, logistics support, performance, and input resources must be considered each time the total system design is assessed. An iterative process is needed since the design of the prime equipment influences logistics support requirements and the logistics support will impact the total system effectiveness and cost. The objective should be to provide the proper amount of support at the proper time. It is important to recognize that too much support can be as detrimental as too little, but proper planning and integration of the logistics concerns into the total acquisition cycle will optimize the system's total performance.

In order to integrate logistics support as one of the prime program criteria along with cost, schedule, and performance, logistics functions must be established for each program phase. These functions must then be implemented in the total system acquisition by identifying specific logistics support requirements and techniques tailored to the maturity of the system design. Tailoring is very important because the lack of it will eliminate the usefulness of any technique and cause management to lose credibility of the process. Decision making will be ineffective.

Emphasis is placed on the design phase of acquisition in this discussion. The logistics functions generally most appropriate to this phase of acquisition include: design coordination and logistics support services, predictions, utilization of design aids, logistics support analysis, logistics provisioning data, design review, and component test and evaluation. The logistics support requirements that must be considered include the logistics support design analysis and the identification of initial logistics resource requirements.

The design attributes; functional design, reliability, maintainability, human factors, and producibility correspond to the following logistics support elements: maintenance planning, test and support equipment, spare/repair parts,

personnel training, and technical data, respectively. Facilities and transportation/handling are logistics support elements that must be considered, but they relate somewhat indirectly to the above design attributes of the prime equipment.

The design attributes and logistics support elements must be of primary concern to the system acquisition manager who's objective is to acquire an effective system. The system effectiveness is a function of the performance parameters, availability (operational readiness) and dependability. Dependability is the effectiveness factor that relates directly to the design phase of the acquisition cycle. Since dependability is a function of operating time (reliability) and downtime (maintainability/supportability) these two parameters, reliability and maintainability provide the necessary linkage between design activities and logistics support requirements. They represent the measurable parameters that the logistics support design analysis employs as the system design engineer works to meet total system effectiveness requirements during the design/development process.

The logistics support analysis during the design phase of major weapons systems should aid in the evaluation of specific characteristics in the equipment design which can be measured in terms of reliability and maintainability features. Alternatives in design such as test approaches, packaging schemes, accessibility features, transportation, and handling provisions should be subject to the analysis.

The logistics support design analysis must be accomplished by the design engineering team in direct response to the customer's requirements. This obviously will require that the design engineering team and the customer be knowledgeable about establishing guidelines for the logistics support analysis. It also will require that the engineering team be made up of both design engineers and logistics engineers who can incorporate the reliability and maintainability (R&M) disciplines into the design process. R&M cannot be limited to the role of verification of design; they must be used as design criteria. These two disciplines are intricately related t initial design analysis and design conc tualization. The myriads of detail decisions and tradeoffs made during design must include R&M concerns. An interrelated analysis that includes R&M and other design analysis techniques must be established. This requires technically strong individuals who are R&M motivated and can convert R&M principles into the product design. Familiarity with past equipment field problems also is desirable. These individuals should perform such tasks as educating the design engineer prior to and during design, analyze the planned system mission profiles, perform in-process design analysis, provide field experience feedback to design engineers, coordinate on design package release, perform tradeoff analysis, and create checklists and tracking systems for managing discrepancies.

These ideas should be considered by weapon system acquisition managers as they evaluate the producer's capability to integrate logistics support into their design activity and use it as a program criteria. The following section of this paper describes a contractual technique, the logistics incentive award fee approach, used in a major system acquisition in the Air Force. The purpose of this logistics incentive award fee was to encourage the producer to incorporate logistics concerns into his design activities.

LOGISTICS EMPHASIS BY PROGRAM MANAGEMENT

Program managers who perform the essential day-to-day functions as the total system acquisition managers must create an environment that encourages and promotes the incorporation of logistics support into the day-to-day decision making process. The following discussion describes how this was done in a major Air Force weapon system acquisition, the A-X/A-10 Program.

During the early stages of the acquisition program of the A-X/A-10 aircraft the requirements to control both acquisition and operations/maintenance costs were established. Design-to-cost goals were developed to control the acquisition costs, but the attempt to lower future operations and maintenance costs during design required the development of an unique management technique.

The technique developed involved the adaptation and application of an operation and support (O&S) cost model with a contractor incentive award fee. The O&S cost model used was a modified version of a cost model developed by Air Force Logistics Command. A detailed description of the model is contained in references 3 and 5. The contractor incentive award fee was devised to encourage the contractor to make design changes that would lower future O&S costs during the full-scale development phase of the program. The award fee was partially based on an evaluation of the results of the O&S cost model at the completion of a field flight test period. This relationship of the award fee to the cost model was established to provide the incentive for both contractor and Government personnel to establish an effective process to man. e and emphasize the logistics support aspects of the system design effort.

The logistics support cost control technique used during the A-10 acquisition program was implemented over a seven-year period. It began in May 1970 during the Competitive Prototype Program (CPP), continued through full-scale development (FSD), and ended in the program production phase with the award fee being made in August 1977. During the CPP phase the contractors were told that the estimated ten-year operation and support costs of their design would be a major factor in the selection of the full-scale development (FSC) program contractor. When the request for proposal for the FSD program was issued it included the requirement that each contractor provide their ten-year O&S cost estimates in a comparative cost model framework. This logistics support design information was used in the source selection for the FSD contractor.

The FSD contractor was required to provide target logistics effect (TLE) estimates for his FSD design early in the FSD phase of the program. The TLE's were developed employing the cost model framework and were the result of estimated reliability and maintainability design characteristics of selected major system line replaceable units. These TLE's were used as goals for the system design effort in terms of logistics support. The engineering changes submitted by the contractor were evaluated in relation to the targets. This provided a method for the logistics engineers and program office managers to conduct a day-to-day evaluation of the system design in terms of logistics support. The first production aircraft were flown to measure the logistics effects of the A-10 aircraft. A test program was established and line replaceable unit removal data was accumulated during the first 5,000 hours of operational flying. This removal data was then used to develop measured logistics effects (MLE). These MLE were compared to the TLE (adjusted for certain program changes) for determining the contractor's logistics design performance and to assist in making the award fee determination.

This entire application is summarized in Figure 1.

The technique described below and used by the A-10 Program included some very important characteristics. It was initiated early in the acquisition cycle. Competition between contractors was still available in the program when the ten-year O&S cost estimates were established. Target logistics support costs were established and defined in a measurable cost framework. A field verification test procedure was utilized. The technique was on contract and it employed a contract remedy/price adjustment. It was incentivised by the award fee. The technique used available Air Force data sources and it was simple, manageable, and understandable.

The technique was used in several decision making situations. During the FSD source selection the O&S cost estimates were evaluated and used as one of the selection criteria. The engineering change proposals (ECP) submitted by the contractor were evaluated and monitored by applying the O&S cost model. The final measured logistics effects were used by the Fee Evaluation Board in addition to other management considerations to make the final award fee determination. It is important to note that the continuous application and implementation of this technique emphasized the concern for logistics support costs to program managers and decision makers throughout the design phase of the program.

The actual impact of this effort on the field operations of the A-10 is difficult to quantify. The A-10 squadrons are experiencing a lower than anticipated NORS rate, and the OR rate has been higher than similar systems during initial field deployment. Logistics support involves such a wide range of functions that to assess the effectiveness of this effort only on an operational basis would be insufficient and misleading. The effort to emphasize logistics concern during the early stages of system acquisition will enhance the accomplishment of the entire logistics support activity.

A-10 ACQUISITION CYCLE LOGISTICS SUPPORT MANAGEMENT TECHNIQUE		
COMPETITIVE PROTOTYPE	FULL SCALE DEVELOPMENT	PRODUCTION
MAY 70	JAN 73	JUL 74
- CPP, RFP CALLS FOR O&S COST	- TLE FROM FSD CONTRACTOR	- FINAL TLE ADJUSTMENTS
- MODEL TO BIDDERS	- ECP TO LOWER O&S COSTS	- BEGIN 5,000 HOUR LOGISTICS EFFECTS MEASUREMENT PERIOD
- IMPROVEMENTS TO MODEL	- PRELIMINARY COST MODEL APPLICATIONS	- END LOGISTICS MEASUREMENT PERIOD
- FSD, RFP FINAL MODEL		- AWARD FEE
- 10 YEARS O&S COST ESTIMATE RECEIVED FROM CONTRACTORS		

CONTINUED LOGISTICS SUPPORT EMPHASIS IN SYSTEM ACQUISITION

The management initiatives in the A-10 Program represent a positive step toward incorporating logistics support concerns in the early stages of major system acquisitions. Similar efforts are being initiated on other Air Force procurements. These activities represent continuing strong support and the increased concern for logistics support as a major system effectiveness factor by acquisition managers.

This continued integration of logistics support requirements as a program management decision criteria can be a major factor in increasing the quality of weapons systems. The following recommendation_ are made to identify actions that will continue to increase the effectiveness of system acquisiton subject to logistics support requirements.

-- Increased program management awareness of logistics support requirements. This may seem to indicate a weakness in program managers, but that is not the thrust of this recommendation. The responsibility for making logistics support visible and manageable in the progr·m office belongs to the logistics engineer and the deputy program manager for logistics. The logistics experts must develop their techniques to give the system program manager the facts he needs to make tradeoff decisions among other program constraints (cost, schedule, performance) and logistics support.

-- Develop effective and credible management techniques. This will entail such things as continued development of logistics cost models, better assessment techniques for determining new systems impact on present capabilities and improved cost tracking systems.

-- Provide adequate incentives. The accomplishment of an analysis of a design in terms of the logistics support requirements requires the application of resources. If it is to be properly accomplished, funds and personnel must be made available. These resources should be explicitely identified by both parties in the procurement. The program management documents shou' specifically identify these dedicated resour s.

-- Obtain greater contractor participation. To get proper emphasis from the contractor of logistics support during design is a very important and difficult task. Clear guidance to the contractor should be provided. Methods for verification of the actual design review in terms of logistics concerns should be established and agreed upon by the contractor and Government engineers.

-- Development of logistics design expertise. The need for individuals with the expertise to incorporate logistics factors into the system engineering design process is great. These individuals must have a working knowledge of the engineering design process and have a detailed understanding of what logistics parameters (reliability, maintainability, and producibility) can be used to evaluate the design by the design engineer.

-- Development of contractual provisions. The development of contractual procedures and terms that express the logistics criteria in clear, understandable terms for efficient contract administration is required. Two areas of concern exist that must be considered. First, the general availability of models relating design parameters to operating and support costs with the required accuracy must be developed. Second, procedures which will accurately measure the support requirements demonstrated by production equipment in the field must be developed and validated. To do this, the final important area of concern must be addressed.

-- Improvement of operational systems history. The need for feedback from the operational environment that will be properly understood by the design engineer is extremely important in the effort to get greater reliability designed into systems. The identification of the kind of information needed and determination of how it should be used must be accomplished with more effectiveness.

SUMMARY

Acquisition management review levels must provide the incentive for improving the system acquisition process. They can do this by emphasizing that the total system must be identified (prime mission equipment and associated logistics support) and that it will be evaluated by the review levels of the acquisition cycle. The program managers and their staffs must develop a complete system management framework for their day-to-day decision making. This framework will depend to a great deal on the usefulness and credibility of the staff specialists who develop and implement the trade-off study techniques used in decision making. To increase the use of logistics as a criteria in system acquisition, the logistics engineers and logistics managers must continue to participate in the early phases of the system acquisition process. To do this they will be required to provide the effective management techniques to justify their contentions.

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NOTE: The views expressed herein are strictly those of the authors and do not necessarily represent the views of the United States Air Force.

EDUCATION AND CAREER DEVELOPMENT

GRADUATE EDUCATION IN ACQUISITIONS AND ASSISTANCE MANAGEMENT: THE NEED, THE EXPERIENCE, THE CHALLENGE

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BACKGROUND

An ever increasing group of practitioners and educators has, for several years, advocated that regionally accredited institutions should offer graduate degree programs with concentrations in procurement and contracting or materials management. As the number of supporters has expanded so too has new terminology more descriptive of the needed program content. The new terminology includes, variously, acquisitions management or acquisitions and assistance management. There are indications that such a degree would be valuable not only to the holder and to the acquisitions community but to our evolving social system. During the last 10 years, a substantial group of masters degree holders with concentrations in Procurement and Contracting has been introduced into the acquisitions management field by existing programs. It would seem that the views and experiences of that group can contribute much to our understanding of the need for such concentrations.

Interest in the development of model graduate degree programs has been accentuated by the Federal Acquisition Institute's (FAI) initiatives as published in the FAI Director's report each month since its inception in October, 1977. As part of the process of formulating such programs, a review of the successes and problems experienced by existing degree granting institutions that have offered similar programs would be useful.

One of the first such programs, the Procurement and Contracting (P&C) program at The George Washington University (GWU) was begun in the Fall, 1968, and continues today. While this paper looks briefly at the GWU program, its major thrust is to examine the idea of creating graduate degree programs in acquisitions and assistance management. It addresses the matter from these perspectives: (1) the need for such programs, (2) the curriculum/institutional environment best suited to such programs, (3) the generally low interest in such programs expressed by accredited institutions to date, and (4) a proposition as to what attributes would interest universities and schools in adopting such programs. In part, the paper is based on a survey conducted in March, 1978 of graduates of the GWU procurement and contracting program. A brief description of the GWU program will perhaps aid readers not familiar with it.

GWU has offered its P&C program as a field of concentration for students pursuing either of two masters degrees, both offered by GWU's School of Government and Business Administration. The two degrees are the Master of Business Administration (MBA) and the Master of Science in Administration (MSA). To date, these two degrees have been distinguished in that the MBA requires the student to accomplish the full common body of knowledge as prescribed by the American Assembly of Collegiate Schools of Business whereas the MSA has not required the full common body.1/ Additionally, at GWU the MBA has been offered as an "on-campus" degree whereas the MSA has generally been available "off-campus" within the Washington, D.C. area. A philosophical distinction exists in that the MBA is conceived as a generalist degree that prepares the student for broadly based business managerial performance and roles in executive decision-making. The MSA is designed to provide the student with the expertise essential to the conception, and effective management and control of large-scale organizational activities.

The P&C program was initiated at GWU with substantial support in the form of student inputs from the armed services. It shortly gained additional support by the input of civilians drawn from the Federal procurement workforce, particularly from the Navy. These early commitments of students--many of them supported on a full-time basis--were essential to the viability of the new program. During the first three years of the program nearly all P&C students were government employees. With the development of the program, the source of students has changed. Increasing numbers of students employed by industrial firms in the Washington, D.C. area have elected the P&C program as they pursued their master's degree work on a part-time basis. Also a number of civilian agency personnel are enrolling for part-time study. In the last [illegible] years a

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1/ Author's note: In 1977 the GWU BBA program was accredited by the AACSB and at present the School is undergoing an intensive self-examination of its masters degree offerings in preparation for their accreditation review. As a result some modification of the master's programs is likely.

small but significant number of students who do not have previous career oriented job exposure have been opting for the P&C concentration as they complete their undergraduate work and begin pursuit of the master's degree.

Overall the P&C program has graduated 251 persons--an average of 25 per year. It currently has 36 MBA students and 88 MSA students enrolled, for a total of 124 graduate degree candidates. Additional students are enrolled in program courses on a non-degree basis.

THE NEED

Attempting to express what constitutes the need for graduate education in acquisitions and assistance management leads to debatable assertions. An extraordinarily complex field of study is involved. This complexity results from the fact that several recognized and established academic disciplines are drawn upon in order to effectively manage such programs. The field involves largely public sponsorship and private performance (but with frequent partial reversal of those roles) of work efforts at the leading edge of scientific and/or technological experience involving either the physical or social sciences or both.

Acquisitions processes embrace a broad spectrum of management activities critical to a central core subject: i.e., the decision to acquire either goods or services. This fundamental decision is the focal point of an unmeasured degree of organizational effort. The magnitude of the effort could range from near total organizational mobilization to the unobservable placement of automated purchase orders. Acquisitions and assistance management, however, is principally involved in the creation and management of relationships between organizational entities to be joined in pursuit of significant common objectives. These common objectives are developed through the articulation of a need, its operational definition and identification of requisite resources. The relationships to be established involve role definition of organizations, costing, risk and responsibility allocations, and execution that assures objective fulfillment.

The educational product needed for this work is a manager with new breadth and a new perspective. This type of manager must be capable of accomplishing his or her objectives even though operating without direct authority to control either performer or sponsor. The management art needed lies in the manager's ability to join independent entities--each with independent organization objectives--into an effective team with a singular set of objectives.

Existing management literature has not adequately addressed the kinds of relationships or the dynamics implied by such organizational interfaces. The initiation and development of a new literature is essential. It must address the concepts of interorganizational management. In its traditional form these concepts are addressed as contractual relationships in which one organization procures the services and material offered by another. More recently a less defined, but well known instrument has increasingly been employed--the grant. Currently grants have become known as cooperative and assistance agreements. These kinds of instruments are merely legal expressions of business relationships. The actual ongoing managerial challenge is a dynamic, and frequently ill-defined, interpersonal and interorganizational combination. The development of managers with such interorganizational capabilities should include challenge by an educational experience that allows them to balance public, private and personal objectives. They should be challenged to seek, to mediate, and to achieve fulfillment on each front in a manner that simultaneously meets the common set of objectives.

The author proposes that a need exists for academic attention focused on developing programs in acquisitions and assistance management. Today's predominant educational mode--short courses conducted in non-accredited settings sponsored by employers to meet specific organizational needs is inadequate.

While the need for degree programs can be assessed in numerous ways the survey of graduates of GWU's P&C program may prove useful in revealing the perceptions of a group that is qualified by both experience and education to make a knowledgeable appraisal of the field.

THE SURVEY

The P&C survey was conducted by use of a questionnaire mailed in March, 1978 to the entire group of P&C graduates based upon latest known addresses. (See Appendix I) Fifty-five undelivered questionnaires were returned and 79 completed and usable questionnaires had been received by April 6, 1978. The data included in this study are based upon that response. The response rate, based upon an assumption that 196 questionnaires were delivered was 40 percent. The resultant sample is well distributed over the population of P&C graduates as is indicated by Table I.

A further insight into the sample is provided by Table II. This table sets forth the general distribution of the respondents by employer group and job group. Based on Table II it appears that two-thirds of the P&C graduates are working within the acquisitions field but several (one-fifth) of them have progressed or moved into jobs with broader managerial responsibilities.

The survey sought to discover the perceptions of P&C degree holders regarding the institutional environment and program content of greatest value for personnel in the acquisitions field. An assumption incident to the survey is that the respondents would be more knowledgeable of the field and of the educational needs of its practitioners than any other easily defined population. All of them have studied and nearly all have practiced in the field. The results are set forth in Table III.

With respect to whether a public administration school or a business administration school is the better institutional setting for P&C programs, Table III provides some insight. It is a tabulation of whether question 1 or question 2 received the higher (strongly affirmative) rating from each respondent. Quite clearly, the respondents were supportive of either (1) the business school environment or, (2) both business and public administration. Only a small group, 11 percent, favored the public administration school over business administration. However, the high number of "equally affirmative" ratings would indicate there should be a place in both types of schools for the acquisitions management field. The breakout of MSA and MBA degree holders in Table III is useful since, while MBA holders might be expected to prefer the business school environment, MSA degree holders are not necessarily oriented toward "business" although they are trained in the administrative and management sciences.

Whereas Table III is limited to indicating which institutional setting is, relative to the other, felt to be needed more, the response to questions 1 and 2 is summarized directly in Table IV. This summary indicates the strength of perceived need for P&C programs in Business and Public Administration schools.

Respondents were strongly affirmative in their view that procurement and contracting programs should be available in public and business administration schools. The two strongest ratings (1 and 2 on a scale of 5) if combined for public administration schools, received 53 percent of respondent ratings while the two strongest ratings for business administration schools received 85 percent. The apparent stronger advocacy of business administration may be attributed in part at least to support of certain content of most business programs. This conclusion is indicated by the responses to question 3 of the questionnaire. Question 3 asked respondents to rate the need for students to be exposed to the full business common body of knowledge and it referred the respondent to a list of subjects representative of the business common body. The response to this question provided the most strongly affirmative response of the entire questionnaire. It is recorded in Table V.

As shown by Table V, 73 percent of the sample answered question 3 with the highest perceived need (1). Also 78 percent of MBA respondents rated it with (1), and for the whole sample 89 percent rated it in the top two categories. Clearly this group of degree holders perceives the business common body of knowledge to be an important element of the knowledge needed by P&C personnel.

INSTITUTIONAL CONSIDERATIONS

Regionally accredited institutions have been slow to embrace degree programs in acquisitions management at either the bachelor's or master's level. Understanding their reasons for slowness is critical, and several aspects of the educational process need to be considered in this context. One of these is the reality that degree-oriented programs are not generally adopted solely because some sponsoring institution--such as the Federal Government--expresses a desire for a particular program. They are more likely to be adopted in response to student pressures derived from opportunities for employment. Opportunities for employment are also critical. Ideally, to justify installation of a degree program, the opportunities should be widely distributed across the economy's institutional framework. Degree programs have limited appeal if, for example, they prepare a student exclusively for an occupation sponsored by a single institutional sector. Occupational mobility is too highly valued a capability among our increasingly professionalized workforce for narrowly conceived management programs to be sustained in degree-granting institutions.

In the field of acquisitions management (or procurement and contracting, purchasing, materials management, or logistics management as various programs may be characterized), there is no need for limited institutional appeal. All levels of Government, diverse public and non-profit organizations, industry and construction plus all other major employment sectors have need for creative talent that knows and understands acquisitions processes and complexities. Thus it would appear that the design of acquisitions management

programs should embrace the demands and needs perceived by a broad group of management people.

CONCLUSIONS

Educational institutions have an opportunity created by the current effort of FAI. They may come forward with innovative educational concepts. The Federal interest in this field provides a strong motivational basis. However, the educational package to which accredited institutions may respond may require several ingredients beyond an expressed need and even beyond resources in dollars. The elements of that package include:

(1) A belief that continued student participation and interest will be present;

(2) A belief that the proposed academic program has multi-sector appeal in our economy;

(3) A philosophical basis and position for the curriculum that addresses all of its elements;

(4) Availability of basic textual and case material;

(5) Academically creditable literary opportunities.

While parts of this educational package exist for acquisitions management, it has not been broadly articulated to date.

TABLE I

DEGREE & DATE OF DEGREE OF RESPONDENTS TO PROCUREMENT AND CONTRACTING QUESTIONNAIRE

Date of Degree	MSA	MBA	TOTAL
1969		3	3
1970		9	9
1971	1	5	6
1972	2	6	8
1973	3	7	10
1974	2	7	9
1975	3	3	6
1976	5	4	9
1977	4	5	9
1978	9	1	10
TOTAL:	29	50	79

TABLE II

EMPLOYER GROUP & JOB GROUP DISTRIBUTION OF RESPONDENTS TO PROCUREMENT AND CONTRACTING QUESTIONNAIRE

		Job Group		
Employer Group	Total	General Management	Materials/Procurement & Supply Management	Other Specialization
U.S. Govt.-Defense Agencies	46	10	35	1
U.S. Govt.-Civil Agencies	12	2	8	2
Private Business Firms	11	3	6	2
Non-Profit Organizations	[illegible]	2	1	0
Public Agencies (not Federal)	1	0	0	1
	[illegible]	17	50	6

TABLE III

PUBLIC ADMINISTRATION/BUSINESS ADMINISTRATION
INSTITUTIONAL SETTING FOR PROCUREMENT
AND CONTRACTING DEGREE PROGRAMS

	MSA Degree Holders	MBA Degree Holders	Total
BA setting preferred	10	27	37
PA setting preferred	4	4	8
Equally affirmative	12	17	29
TOTAL	26	48	74

TABLE IV

STRENGTH OF PERCEIVED NEED FOR PROCUREMENT
AND CONTRACTING PROGRAMS IN BUSINESS
AND PUBLIC ADMINISTRATION SCHOOLS

	Strongly Affirmative				No	
Rating	1	2	3	4	5	Total
Public Administration	23	16	24	8	3	74
Business Administration	41	21	8	1	2	73

TABLE V

PERCEIVED NEED FOR PROCUREMENT AND CONTRACTING STUDENTS
TO BE EXPOSED TO THE FULL BUSINESS
ADMINISTRATION COMMON BODY OF KNOWLEDGE

Degree Respondent Holds	Strongly Affirmative				No	
	1	2	3	4	5	Total
MBA	36	8	0	1	1	46
MSA	19	4	4	1	1	29
TOTAL	55	12	4	2	2	75

APPENDIX I

The questionnaire included several questions. The section pertinent to this study was:

Having completed a degree with a procurement and contracting major, your evaluation of the following questions would be most valuable and would aid us in our planning for the future.

Based on your experience, indicate how strongly you see a need for:

	Strongly Affirmative 1	2	3	4	No 5
1. P&C programs in a public administration school.	1	2	3	4	5
2. P&C programs in a business administration school.	1	2	3	4	5
3. Exposure of P&C students to the full business administration common body of knowledge (subjects as identified on page 2).	1	2	3	4	5

A CRITICAL REVIEW OF DEPARTMENT OF DEFENSE CIVILIAN PROCUREMENT CAREER DEVELOPMENT PROGRAMS

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NOTE: This paper is a condensation of a report prepared in August, 1977. Since that time, organizational, definitional and scope changes have occurred in the acquisition/contracting/procurement field. These changes have not been implemented into the career program, and, consequently, no attempt has been made to incorporate such changes into this paper. However, the findings and recommendations remain valid for the current career program and are applicable to a program covering either the acquisition or contracting career fields. Although the research was performed in the procurement career program, many of the conclusions and recommendations are applicable to other career fields.

INTRODUCTION

During FY 1977, the Logistics Management Institute (LMI) reviewed and evaluated the DoD civilian procurement career program, focusing on certain elements to determine where problems existed and to recommend actions for improvement.

The study methodology included a review of career development and management literature, DoD directives and instructions, and Civil Service Commission (CSC) regulations. To supplement the written information, we visited selected offices and organizations and attended meetings of the Defense Procurement Management Board (DPCMB), its Subcommittee on the Automated Career Management System (ACMS), and the ACMS Test Team.

FINDINGS AND RECOMMENDATIONS

The study concentrated on eight program elements: personnel recruitment, mandatory training requirements, equivalency tests, career appraisal procedures, personnel inventory and referral systems, personnel mobility, executive development, and organization for career development.

A. PERSONNEL RECRUITMENT

No significant problems were found in the recruitment of new personnel into the procurement career field. In the preparation of new employees for a procurement career, however, some deficiencies exist. The current program applies to civilian procurement employees in DoD components at the GS-5 and above levels in the GS1101/1102/1103/1150 series. For other positions and series, the career development program applies if: (1) more than 50 percent of the duties and responsibilities involve pre-award and post-award contracting and purchasing functions, and (2) the experience qualifications for entry into one of the four series are met.

Positions in the GS1105 (Purchasing) and GS1106 (Procurement Clerical and Assistance) series are excluded from the current program unless the above conditions are met. However, the major or descriptive differences between GS1105/1106 and GS1101/1102/1150 positions is that the former emphasize manual skills and the latter place greater emphasis on mental and interpersonal skills. We, therefore, suggest that the relationship between the career program for GS1102 and the training program for GS1105/1106 should be made closer for two reasons. First, since the GS1105/1106 personnel are performing the detailed procurement tasks, the procurement training program should include them to ensure effective job performance. Second, more attention to GS1105/1106 personnel would improve implementation of upward mobility programs within the DoD, as recommended in a recent GAO report.[8] Another personnel recruitment problem is that none of the current DoD intern programs cover all entrants. This is contrary to the CSC requirement that:

> Each program is to include <u>all employees</u> in the agency entering an identified career field at any level below the recognized journeyman <u>without regard to their source of recruitment</u>. (Emphasis added) [5]

<u>Recommended Actions</u>

(1) Include training for GS1105 and 1106 in the overall civilian procurement training program.

(2) Comply with the CSC regulations which require training of all entrants.

B. MANDATORY TRAINING REQUIREMENTS

The CSC does not impose specific types of mandatory training upon a career function. It only requires that first-line supervisors be given suitable initial training and that entrants be given proper orientation.[3][4]

Within the DoD,[17] careerists must complete "mandatory" courses or approved equivalent courses or pass the equivalency tests. However, this requirement is not being rigorously enforced.

In 1970, the GAO reviewed the DoD procurement career program and discovered that many careerists were not completing "mandatory" training. [7] Little improvement was noted during a follow-up survey in 1975[9] when GAO found that, of 13,882 employees in the career work force, 2,776 had completed their mandatory training, 6,855 were exempt under the "grandfather" clause, and 360 were under waiver due to being less than one year in grade at their current position. Thus, 3,880 employees were found to lack the "mandatory" training required at the previous level.

The condition has not improved. During 1977, only 31% of the career personnel needing a particular course completed it.[10] However, since the qualification standards, as set forth by the CSC [6], do not include specific educational or training requirements, the DoD cannot impose such requirements unilaterally. An agency can only recommend that certain education or training would be helpful in carrying out the duties and responsibilities of a specific job.

The DoD will soon have an effective means of determining specific job training needs -- the ACMS appraisals. These appraisals, consisting of a set of technical and standard factors for each series, are conducted for persons intended to be at the GS-13 level and above and are used for referral purposes. By analyzing the individual needs shown by the appraisal forms, specific training requirements can be formulated. ACMS contains registrations of all program employees below GS-12 and the CSC requires that an annual evaluation of each civil service employee be made. Therefore, it appears appropriate for DoD to add an appraisal requirement for all ACMS registrants. Such an addition is not intended to alter the present practice of filling positions below GS-13 at the discretion of installation managers. Rather, the appraisals would be used for training purposes only.

Recommended Actions

(1) Confine mandatory training to those levels authorized by CSC regulations.

(2) Use ACMS appraisals to pinpoint the subjects and skills an individual needs in order to perform his job satisfactorily and to prepare him for greater responsibility.

(3) Analyze current procurement courses to determine how effectively they meet the needs indicated by the ACMS appraisals.

C. EQUIVALENCY TESTS

Currently, procurement employees are not required to take mandatory training if they (1) have successfully completed an equivalent course, or (2) have passed the Procurement Knowledge Test (equivalency test) for the course.

There is a serious problem in the lack of communication between civilian personnel offices administering the equivalency tests, the schools preparing the tests, and the functional managers. One consequence of this information deficiency is that it is unclear at the monitoring levels whether the most current tests are being given. Because the equivalency tests are the final examinations of the mandatory courses, and hence, vary in emphasis as changes occur in the functional field, such lack of communication can hinder the upgrading of the procurement career force by not properly testing on current subject matter. Furthermore, this lack of feedback makes it difficult for the schools to assess the quality (and needs) of courses.

Recently, the Army accepted responsibility for supervising procurement equivalency tests and is correcting this deficiency. Therefore, no further recommendation is needed.

D. CAREER APPRAISAL PROCEDURES AND PERSONNEL INVENTORY AND REFERRAL

The DoD Civilian Procurement Career Manual defines career appraisal as

> that process of inventorying and evaluating the attributes and potential capabilities of each employee. It includes analysis of career training needs for orderly progression within the career field and the planning for fulfillment of those needs.[17]

The manual also stresses that career appraisal should be an ongoing, day-to-day responsibility of the supervisor. Annual formal career appraisals are also required.

DoD has maintained the Centralized Automated Inventory and Referral System (CAIRS), which was intended to contain a current resume for each employee in the procurement career program. The purpose of the referral system was to provide management with a listing of the best qualified candidates for procurement position vacancies at the GS-13 level and above while ensuring that all eligible candidates are considered for job openings and encouraging movement across geographical and departmental boundaries.

CAIRS has not been successful in achieving its purposes due to the inadequacy of its single-number appraisal process. Too many referrals for an opening results when this inadequacy is coupled with CAIRS' emphasis on experience and its inability to identify individuals not interested in a job change.

ACMS is to replace CAIRS and is presently being tested. Its most significant feature is a new appraisal system which provides for evaluation in a large number of job-related factors, thereby permitting a more accurate review of an individual's strengths and weaknesses.

Recommended Action

Continue to monitor the implementation of ACMS and evaluate its effectiveness for one year after on-line operation starts.

E. PERSONNEL MOBILITY

Mobility includes occupational, organizational, program, functional, or geographic change. The CSC recognizes that mobility can be an important factor in a person's career and the Military Services encourage mobility and often make it a requirement for entry into certain programs.

The CAIRS Annual Report for 1977 revealed that, of 271 selections made during that year, 14% of the selectees crossed component lines, 12% changed major organizations within the component, 4% changed classification series, and 21% moved to another geographical area. Evidence of executive mobility in the DoD was also presented in a study[19] covering Federal executives. The portion of the study dealing with 62 supergrades found that 91.9% had experienced "organizational mobility," 77.4% had private sector experience, and 46.8% were "geographically mobile." These data show that civilian Federal executives are mobile and mobility need not be a concern in civilian procurement career development.

F. EXECUTIVE DEVELOPMENT

Problems exist in reviewing executive development programs because of the many different definitions of "executives." In its policy guidance, the CSC used the term "executive" to mean GS-16, 17, 18, or equivalent.[1] In developing its guidelines, however, the CSC tended to use characteristics descriptive of a "general" manager. This has led to the inclusion of individuals in supervisory positions at lesser grades who had relatively broad operational responsibilities. Another CSC issuance states that the term "managerial position" refers to the duties of a position, regardless of the grade or salary.[2] In applying this latter standard for identifying executives, there are many GS-13s, 14s, and 15s in field installations who satisfy it.

Each agency is required to have a formal high-potential identification system and the CSC permits each agency to make its own decisions regarding the identification process best suited to its managerial manpower needs.

In a study[18] concerning civilian executive development programs in the DoD, it was found that DoD management perceived the following inadequacies in the programs: (1) absence of a well-defined system for early identification of potential executive talent; (2) unsatisfactory means for tracking the progress of high-potential executive candidates; and (3) development of civilians tends to be unsystematic and unreliable. None of the DoD components had a fully operative executive development program in compliance with CSC regulations, although most have policy implementation guidelines and regulations.

Recommended Actions

(1) Redefine "executive" so as to avoid ambiguity and to enhance uniformity in the use of executive development programs.

(2) Apply the recommendations in Section B above to determine the training needs of executive personnel.

(3) Utilize the ACMS appraisal system to identify potential executives and track their progress more efficiently.

G. ORGANIZATION FOR CAREER DEVELOPMENT

A number of DoD directives and instructions provide the basis for career development programs.[11][12][14][15]

Two additional instructions are relevant in the procurement career field. DoD Directive 5010.16 [13] establishes the Defense Management Education and Training (DMET) Board whose responsibilities include developing policy guidance and plans for management training and for reviewing and approving education and training programs. DoDI 5100.58 [16] establishes the Defense Procurement Career Management Board which assists the DoD functional head in carrying out his responsibilities for the operation of the career program. The DPCMB is a part-time board which meets approximately once a month.

A 1970 GAO report[7] stated that an ineffective working relationship existed between these two boards, having a negative impact on the procurement career program. The career

program was not likely to succeed in the absence of a single focal point with full responsibility for effectiveness.

The problem which GAO identified still exists. A major contributor to the management problem appears to be the ambiguity that characterizes career program directives. Similar ambiguities concerning the proper roles of the civilian personnel and procurement functions also exist at the DoD component levels.

Our findings indicate that greater precision in the assignment of organizational responsibilities might resolve this problem. This can be done by revising the basic career program directives to create responsibilities similar to the following:

Responsibility of
Manpower & Training Office

- Recruitment
- Entry program administration
- Course scheduleing
- Inventory & referral systems
- Personnel scheduling for training
- Personnel appraisal development
- Administration of training resources

Responsibility of
the Functional Office

- Course content
- Job training requirements
- Conduct personnel appraisals
- Maintain liaison with MRA&L
- Evaluate effectiveness

The rationale for such a division of responsibilities is that manpower and training offices possess the expertise necessary to develop and administer the career programs, while the functional offices possess the expertise necessary to determine the requirement for training and, therefore, the content of each program.

Recommended Action

The OSD should clarify and simplify the multiple directives regarding career programs.

SUMMARY

This paper notes a number of deficiencies in the present DoD civilian procurement career development program: low utilization of training courses, non-compliance with CSC regulations, and diffused organizational responsibilities.

In so dynamic and highly regulated a field as governmental acquisition, the case for a structured career development system is very strong. Without formal training, the risk of retaining obsolete concepts and procedures in current operations is high. In addition, DoD's career development program must be supportive of the Federal Government's commitment to the upward mobility program and true equality of opportunity. Affirmative management action toward meeting these goals necessarily involves a system concept of career development. This concept involves a reformation of the goals, definitions, and structure of the entire program with emphasis on individuals' career plans and DoD's organizational requirements. The essence of the system should be "mandatory" career development rather than "mandatory" training.

For the proposed system to be effective, a control/evaluation mechanism is needed. The new ACMS should be used for this purpose. ACMS, as currently defined, includes evaluation of the employee's needs for further training in specific job functions. It also provides for identification and planning for employee and agency future needs. Expanded use of the ACMS system can result in specific identification of training needs, better planning for training resources, more effective use of existing resources, and more effective control of resources.

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"SHOULD COST"-WHY ARE WE NOT UTILIZING THIS CONCEPT TO A GREATER EXTENT?

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INTRODUCTION

For almost four decades the single largest buying agency in the United States (perhaps the world) has been the Department of Defense(DOD). With the exception of the past few years, DOD has traditionally received the major share of the federal budget and if current world conditions follow their present course a greater share of the budget must again be allocated to defense.

Department of Defense agencies do expend billions annually for items which do not contribute to increasing our living standard. Because of their ambivalent nature these expenditures naturally come under close scrutiny and even become a "whipping boy" for certain members of Congress, pacifists, and unilateral disarmament advocates. The fact that the DOD budget is annually spent on contracts with thousands of private firms and educational institutions employing several million people is generally overlooked. Furthermore, that our national security is based upon our military strength is apparently of lesser importance to those with more immediate personal motives. On the otherhand, these groups, unknowingly, may be the conscience of our society and are providing the catalyst we require to strive ever harder to obtain the necessary defense at the least possible cost. This is a goal we have not achieved according to repeated cost overruns in many DOD contracts. With reference to such cost overruns, the frequent unanswered question is--<u>WHY?</u>

In an effort to answer this question, the author researched several areas and found the "Should Cost" concept a most logical answer and solution to the problem and developed this into a 1975 Doctoral Dissertation.

Many people are unfamiliar with the term "Should Cost." Unfortunately, there is no universally accepted definition. It is primarily an approach to the pricing of "High-Cost" hardware, bought from private industry operating in a non-competitive environment, and which assures that a contractor's proposals do not include the cost effect of past inefficiencies or uneconomical management practices. Furthermore, it attempts to supply the scope and detail necessary to determine what weapons system, or major component thereof <u>ought to cost</u>, assuming reasonably attainable economy and efficiency in the contractor's operations, and still permitting a contractor a reasonable profit, if he operates prudently. It does not develop a "rock-bottom" figure which would require a contractor to drastically alter his operations. The government does not seek, in the "Should Cost" method, data by which the contractor will be told how to conduct his business. Nor does it assume that contractors should be able to forsee all the intangibles and unknowns confronting him during the life of a contract. It simply attempts to eliminate the perpetutation of past inefficiencies and uneconomical management practices by contractors. A Spin-off to this should result in a more competitive contractor in the future.

The first "Should Cost" study was conducted by the Navy at the direction of the former Secretary of Defense, Robert S. McNamara, in 1967. The location was the Pratt & Whitney Aircraft Company's engine plant in East Hartford CT. There was great concern for the company's high proposed contract price for the TF-30 Jet engine destined to power the F-111 aircraft. The outcome of the study reduced the estimated contract price by $100 millions. The Armed Services Procurement Regulations (ASPR), Army, Air Force, and Navy directives spell out the "Should Cost" concept.

OBJECTIVES CONTAINED IN THE DISSERTATION RESEARCH

Accepting the premise that the "Should Cost" concept could answer the earlier question, "Why do major weapons systems contracts experience frequent cost overruns?", the primary objective for the study was to determine the educational requirements to prepare future "Should Cost" team members to function effectively in their specific tasks.

Considering the recency of "Should Cost", the following specific objectives guided the conduct of the study: 1. To identify the key elements of "Should Cost." 2. To identify any association as well as any significant differences in the responses to questions in each of the key element areas provided by persons who served as team <u>Leaders</u> compared with the responses to the <u>same</u> questions by team <u>Workers</u>. 3. To identify any association in the responses toward "Should Cost", in general, between the two groups--Leaders vs Workers. 4. To identify any association in the responses toward "Should Cost", in general, between those who participated in such effort prior to January, 1971 as opposed to those participating since January, 1973. 5. To identify any association in the responses toward "Should Cost", in general, among Air Force, Army, Navy, DCAS, and DCAA personnel as independent demographic groups. 6. To identify the effect of formal training in preparing

team members for their tasks, as compared with those who had received no formal training prior to serving as a team member. 7. To identify the educational needs for future team members as perceived by former team Leaders as opposed to former team Workers.

ASSUMPTIONS APPLIED IN THE RESEARCH

Public demand for more domestic programs will increase, resulting in pressure to cut or, as a minimum, not permit defense spending to grow. This implies more careful scrutiny of defense contractors.

Inflationary trends and increasingly complex technology assures continued high cost for defensive weapons.

Either, or both, of the above will tend to expand the application of "Should Cost", to include lesser procurement actions currently excluded.

World tensions, especially in the Middle-East, will remain high causing continuing demand for our military hardware.

"Should Cost" could become a two-edged sword. Where it is now directed solely toward improving contractor efficiency, it might readily be broadened to encompass improving government responsibility as a party to the contract; e.g., correctly written specifications, accurate drawings, timely delivery of serviceable government furnished items, and realistic delivery schedules.

That a single elite DOD agency might be created, staffed with carefully selected qualified persons, and assign the responsibility for all "Should Cost" analyses to this agency rather than permitting each service to perform independent studies.

LIMITATIONS

Two distinct limitations were applied to the research effort: 1. The names of former "Should Cost" team members, furnished by their respective agencies, must be accepted as the total population. (Persons who had transferred, or retired with no immediately available forwarding address, and those deceased were excluded.) The extensive effort by persons within those Services in screening personnel records, with the full knowledge that the research effort was officially approved, would indicate that the list of names developed does represent the total population. 2. The research was not intended to develop any specific curriculum or course of study for future "Should Cost" team members. The findings may, however, serve as a guide in such effort.

RESEARCH METHODOLOGY

The research was the first attempt within DOD to study the attitudes toward "Should Cost" by former team members. The methodology was primarily two-fold; inductive and statistical. For the former, the author sought to draw general conclusions from an examination of literature, official documents, personal interviews, and an evaluation of responses to a survey questionnaire sent to fifty percent of the identifiable former "Should Cost" team members randomly selected from the total population.

One specific result of the first method was the firm evidence that four key element areas were identified with the "Should Cost" concept. (These were utilized in the statistical portion of the research). They are: Planning; On-Site Data Collection and Evaluation; Report Writing; and Negotiations. Responses to questions in these key elements constituted a major factor in the research.

The statistical portion of the research attempted to detect either an association or significant differences in the responses to questions in one general category area and four key element areas by former "Should Cost" team Leaders compared to responses to the same questions by former "Should Cost" team Workers.

Thirteen hypothesis were developed and tested to measure the perceptions of former "Should Cost" team members. The Spearman rank correlation coefficient (r_s) was applied to measure the association in responses to the same questions answered by the two specific groups--Leaders and Workers. The chi-square (X^2) test was utilized to measure any significant difference in responses to the same questions by the two groups. Both tests were concerned with responses to questions relating to the four key elements. The researcher was willing to accept a five percent probability of a Type I error rejecting the null hypothesis when it is true, thereby setting a significance level of .05.

POPULATION AND SAMPLE

In order to assure that responses to the questionnaire did, in fact, represent the total population, a random sampling technique was utilized to select fifty percent of the former "Should Cost" team members identified by the Army, Air Force, Navy, Defense Contract Administration Service (DCAS) and the Defense Contract Audit Agency (DCAA). The latter two, although not procuring agencies, did have

members serving on "Should Cost" teams.

A total of 378 names and addresses were obtained in the following proportion: The Army Material Command (now DARCOM), 196 people; Air Force Systems Command, 96; Navy Material Command, 8; DCAS, 33; and DCAA, 45. The small number of Navy people was attributed to the few such studies conducted by the Navy after they initiated this concept in 1967. Most of the Navy's former team members had either retired or were not readily traceable. The names were arranged alphabetically within their respective agencies and numbered consecutively. A validated list of random numbers was applied to select the sample to be surveyed plus a ten percent alternate group. Each selectee was assigned a Schedule Control Number and suffix letter for identification, since names or other coding might have invalidated the research. The relationship of each name to the Control Number and suffix letter was known only to the researcher.

Responses to the questionnaire was ninety-two percent. Of 190 questionnaires, 160 were utilized. This represented 84.2 percent of the sampled population. This reduction was necessary because fifteen completed questionnaires arrived after the cut-off date and could not be included in the study.

A Honeywell 635 computer was extensively employed during this study. A special computer program was developed to record and store responses. Each response on the questionnaire was coded and transcribed onto a scan sheet which the computer read and stored. Relationship studies are infinite. Only a fraction of the available information was utilized in this study.

LITERATURE RESEARCH

Three computer interrogations were conducted in search of literature on the topic "Should Cost." The Educational Resources Information Center (ERIC) and the Current Index of Journal Entries (CIJE) both proved negative. The Defense Documentation Center, Cameron Station, Virginia, did provide a brief listing of articles in Procurement related periodicals. These proved peripheral, at best. The scarcity of published material is believed a reflection of the recency of this concept.

PERSONAL INTERVIEWS

Twenty-seven people were privately interviewed. Six Air Force; twelve Army; two Navy; four DCAS; two DCAA; and two from the General Accounting Office (GAO). Only two of this number were willing to be quoted which, by itself, might lead to all kinds of conjecture.

FINDINGS

Perhaps the most relevant feature of the findings was the extremely high percentage of completed questionnaires returned to the researcher (92 percent). The population included both team Leaders and team Workers. The Leaders were either Team Chiefs, Deputy Team Chiefs, Operations Officers, or Sub-Team Leaders. The Workers comprised all other team members. More importantly, every Service, Agency, and Sub-Agency involved in "Should Cost" studies are represented in the research.

The researcher anticipated six possible curves which might be drawn to show the opinions expressed in the survey questionnaire by two independent groups (team Leaders) and (team Workers) in a common area. Their responses were tabulated on a range from a low score of "1" to a high score of "5". Based upon earlier interviews and a pre-test questionnaire, the researcher anticipated the responses would ultimately evolve into a bi-modal curve with the team Leaders scoring on the higher side and team Worker responses generally scoring on the lower half of the scale. For further clarification, the lower ratings on the scale would indicate dissatisfaction with "Should Cost" experience and vice versa.

Had a curve been constructed to reflect the actual responses to the questionnaire by the two groups (Leaders vs Workers), the resulting curve would have been skewed well to the right, or high side of the scale. This would reflect that both groups had a positive attitude toward "Should Cost". It would also support the researcher's earlier thesis that the "Should Cost" concept has merit and an educational program for future team members is worthy of consideration.

The most significant finding during the analysis was the consistency with which the null hypothesis were rejected. Testing the association in responses to questions between the former team Leaders and Workers, in the four key element areas, only one element was found (Report Writing) where the computed (r_s) failed to reject the null hypothesis. A probable reason for the failure to reject the null hypothesis in this element is the controversial aspect of "Report Writing." The Air Force does not write a report as it generally understood in the "Should Cost" concept. Instead it prepares a Price Negotiation Memorandum (PNM). The attitude expressed by team members from the other services and agencies was that the Air Force's PNM did not satisfy the requirement of "Report Writing." More importantly, they did not see the Air Force effort as being a "Should Cost" study

because the Air Force does not use the full team approach.

Another unanticipated finding was the Navy's reluctance to utilize this concept, even though they gave it birth in 1967. As a consequence the General Accounting Office has been highly critical toward the Navy. No clear reason for the Navy's position was established by the research. On the contrary, the Army has been applying the "Should Cost" studies regularly and with excellent results in reducing contract costs.

In addition to the circled responses on the questionnaire required for the statistical measurements, comments were also solicited. One hundred thirty-three were provided. These comments were recorded and ranked according to their frequency. Examples were: "Supervisors will not release their best people to serve on "Should Cost" teams." "Contractors resist these studies"; "Lack of understanding the purpose and objectives of these studies"; "Not enough time to plan adequately"; and "Communication is vital." These comments added a dimension which reinforced the statistical findings; the belief that "Should Cost" studies are highly beneficial. However, the method of organizing the teams, their preparation for the effort, the conduct of the study, etc. all need further review and overhaul

The single most consistently low rated response was to the question, "Would you like a permanent assignment as a "Should Cost" team member?" The reason for this low rating, in addition to the frequently appearing comments cited above, were the long absences from families, the effort demanding twelve hour days and six days per week without extra remuneration or compensatory time off, and no expense money to return home occassionally during the study.

CONCLUSIONS AND RECOMMENDATIONS

Several general conclusions and recommendations are based on this study: 1. The "Should Cost" concept is sound, however, it is lacking in several aspects. 2. A formal training program would help future team members.
3. The comments provided would provide a sound basis for developing an educational program for future team members. Progress through such a program as a "team" would be most beneficial. 4. Change the procedure for selecting team members. Selection prerogative must be above the immediate supervisory level.
5. Standardize "Should Cost" procedures for all services. 6. Initiate such studies earlier in the procurement cycle, preferrably during the research and development phase.
7. Contractors need to be informed of an impending "Should Cost" study at time of initial solicitation. There appears little justification for withholding such information until after the contractor submits his proposal. 8. Contractors should be appraised of the benefits "Should Cost" studies may provide their company. That they would become more competitive in the future is manifest. 9. Include General Accounting Office personnel on "Should Cost" teams. This would provide the team with GAO expertise in a timely manner and minimize a costly duplication of effort: each procuring agency engages in follow-up studies as does the GAO. 10. Consideration should be given to establishing joint Government-Industry "Should Cost" teams. Since a major portion of DOD procurement costs are incurred in sub-contracting by a prime contractor, joint studies warrant attention. 11. Apply some form of "Should Cost" toward procuring agency activities to insure the government provides accurate drawings, clear specifications, realistic delivery schedules, and servicable government furnished components at the proper time and in required quantities.

A NEW LOOK AT PROFESSIONAL CERTIFICATION

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ABSTRACT

Professional certification, as now offered by various private associations, may be a feasible approach to increasing procurement professionalism in the public sector, according to a study recently completed by the authors. This method of encouraging professionalism has been very beneficial when employed in the private sector. There are, however, a number of cautions which must be observed if such programs are to be offered by the public sector, as shown by the experience of private associations in developing these programs.

Approximately sixty private certification programs offered by professional associations were contacted, and in-depth studies conducted by field interview with the managers of nine of these programs. In every case the associations are enthusiastic about their programs and plan to continue them. A number of individuals who had been certified also were contacted and their views solicited. In general, the attitude of those certified also was favorable, although perhaps not to the degree found in the sponsoring organizations.

Professional certification is not, of course, a new concept. Certification programs have been deeply rooted in the structure of the traditional professions for at least one hundred years. They developed for a combination of reasons, including the desire of the professions to raise their professional standards by establishing qualifications for entry, the encouragement and recognition of skills development, and the enhancement of the prestige of the professional or the profession in the eyes of the public. Also, in some cases, self-certification was initiated by professions to eliminate abuses and preclude government intervention and regulation. In other instances, certification was developed for economic reasons, primarily to reduce the danger of an oversupply of skills which result in increased competition and lower rewards.

Professional validation and some form of certification are becoming increasingly important. Many of the professions which have traditionally had some form of certification are reviewing their standards and processes for continuing professional validation. Additionally, many professions which previously had no established standards or processes for professional recognition have seriously embarked upon certification programs. To give some indication of the range, certification programs have existed or been initiated in recent years in finance, accounting, engineering, personnel and industrial relations, hospital administration, information sciences, insurance, banking, traffic and transportation, contracting, procurement, material management, and management.

The following are some of the preliminary findings of the study:

1. Certification programs have been a strong and effective force in increasing professional awareness, pride and confidence in nearly all organizations investigated. Officials and members alike speak with enthusiasm of their certification programs.

2. Examinations are essential to effective certification programs. Of one group of thirty programs investigated, only one permitted experience to be used in lieu of examinations. If a certification program is to have "teeth" and be effective, this form of objective quality control is essential.

3. "Grandfathering," or waiving examinations for practitioners with certain levels of experience, is a highly controversial issue, with good arguments both for and against this technique. The study found that while "grandfathering" may be unavoidable in some cases, the less grandfathering the better, and that, if possible, grandfathering should be eliminated completely. Grandfathering often dilutes the effectiveness of programs and weakens quality control.

4. One of the major advantages of certification programs for all professions is that they force a disciplined examination and identification of the body of knowledge of the profession. Many professions have existed for years with only a loose, vague appreciation or understanding of their own concepts, techniques, theories, and practical applications. The requirement for certification examinations forces a profession to state these things clearly and concisely.

COST AND FINANCIAL ANALYSIS

AN ANALYSIS OF THE CAS 410 TRANSITION METHOD

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INTRODUCTION

Cost Accounting Standard (CAS) 410, "Allocation of Business Unit General and Administrative Expenses to Cost Objectives," (1) provides criteria for the allocation of business unit general and administrative (G&A) expenses to business unit final cost objectives based on a beneficial or causal relationship. One of the fundamental requirements of the standard is that the G&A expense pool of a business unit shall be allocated to final cost objectives of a cost accounting period by means of a cost input base (2) representing the total activity of the business unit. A business unit whose disclosed or established cost accounting practice prior to 1 October 1976 was to use a sales or cost of sales allocation base may elect to use a transition method contained in Appendix A of the standard in lieu of an equitable adjustment under the CAS clause. According to the CAS Board (3), the transition method was designed to avoid potential disputes, minimize the impact of shifting from a sales or cost of sales base to a cost input base, and avoid the need to use the equitable adjustment provision of the CAS clause to reprice prime contracts and subcontracts. In general the transition method provides that G&A expenses will continue to be allocated to contracts with effective dates prior to the applicability date of the standard (pre CAS 410 contracts) by using a sales or cost of sales rate and base, until these contracts are completed. At the same time, G&A expenses will be allocated to contracts with effective dates subsequent to the applicability date of the standard (post CAS 410 contracts) by using a cost input rate and base. The simultaneous use of different rates and bases for different classes of contracts continues until all pre CAS 410 contracts are completed. A consequential result of the transition method is aggregate G&A expense allocations which exceed actual G&A expenses incurred by the business unit (4).

(1) 4 CFR 410

(2) Total cost input, value added, or single element

(3) CAS Board Prefatory Comments to CAS 410, 41 Fed Reg 16,141 (1976)

(4) It is also possible to have an underallocation of G&A expenses in a given accounting period under certain circumstances. Over the entire transition period, however, there will be a net overallocation of G&A expenses.

This paper presents the results of research conducted for the purpose of better understanding the overallocation of G&A expenses under CAS 410 and for evaluating various policy options for dealing with problems engendered by the overallocation. This paper does not attempt to treat a number of quite complicated legal and accounting issues which are also germane to establishing a DOD position on the overallocation problem, except to the extent necessary to provide perspective and context for the research conducted. The problem of attributing overallocated G&A expenses to different categories of contracts is discussed, and an attribution model is developed. Policy options for dealing with overallocated G&A expenses are identified and discussed, along with a computer model which was developed for simulating these options for various business units. The paper concludes with a discussion of the policy option selected for implementation within DOD.

OVERALLOCATION

Figure 1 provides a summary of the CAS 410 transition procedure which has two main features - the simultaneous allocation of G&A expenses using different rates and bases, and a suspense account provision, which was designed to prevent <u>overreimbursement</u> (5) of G&A expenses. The mechanics of the transition accounting procedure are illustrated in figure 2, which utilizes data from the example contained in CAS 410, appendix A. This figure shows how allocations are made over a three year transition period.

In order to understand the overallocation, it is first enlightening to perform a simple graphic analysis. Figure 3a, based on example year 1978, illustrates how the allocation bases overlap, which results in an overallocation, shown by the shaded area. The overallocation can be calculated from the graph as:

$$(\$1850 - \$1700) \times .125 = \$18.75$$

Figure 3b, based on example year 1979, is a more typical situation where there are differences in both the G&A rates and the allocation bases. Here the overallocation can be calcucated from the graph as:

(5) It is important to distinguish between overallocation and overreimbursement. Here overreimbursement relates to a situation where a contractor would receive payment for overallocated G&A expenses and maintain this cash flow advantage into perpetuity.

FIGURE 1

TRANSITION METHODOLOGY

- G&A FOR CAS COVERED CONTRACTS AWARDED PRIOR TO THE EFFECTIVE DATE OF CAS 410 WILL CONTINUE BEING ALLOCATED ON A COST OF SALES BASE.
- G&A FOR CAS COVERED CONTRACTS AWARDED AFTER THE EFFECTIVE DATE OF CAS 410 WILL BE ALLOCATED ON A COST INPUT BASE.
- AN INVENTORY SUSPENSE ACCOUNT EQUAL TO THE BEGINNING INVENTORY OF CAS COVERED CONTRACTS ON THE EFFECTIVE DATE OF CAS 410 IS ESTABLISHED.
- IF THE ENDING INVENTORY OF CAS COVERED CONTRACTS AWARDED AFTER THE EFFECTIVE DATE OF CAS 410 BECOMES LESS THAN THE AMOUNT IN THE INVENTORY SUSPENSE ACCOUNT, THE GOVERNMENT RECEIVES A CREDIT IN THE AMOUNT OF G&A ALLOCATED TO CAS COVERED CONTRACTS IN THAT YEAR COMPUTED AS FOLLOWS:
  - THE DIFFERENCE BETWEEN THE INVENTORY SUSPENSE ACCOUNT AND THE ENDING INVENTORY OF CAS COVERED CONTRACTS TIMES THE COST OF SALES G&A RATE FOR THE FIRST YEAR OF TRANSITION.
- THE INVENTORY SUSPENSE ACCOUNT IS THEN REDUCED BY THE AMOUNT OF THE DIFFERENCE BETWEEN THE INVENTORY SUSPENSE ACCOUNT AND THE ENDING INVENTORY OF CAS COVERED CONTRACTS.

FIGURE 2a

	Contracts Prior to 1Jan78			Contracts After 1Jan78			
Year 1978	Non-CAS Work	CAS Fixed Price Work	CAS Cost Contracts	Non-CAS Work	CAS Fixed Price Work	CAS Cost Contracts	Total
Beginning Inventory	$300	$200	0	0	0	0	$500
Cost Input	400	600	700	500	500	300	3000
Total	$700	$800	$700	$500	$500	$300	$3500
Cost of Sales	600	550	700	450	400	300	3000
Ending Inventory	$100	$250	0	$50	$100	0	$500

G&A Rates

Cost of Sales $375/$3000 = 12.5%

Cost Input $375/$3000 = 12.5%

G&A Allocation							
Cost of Sales	75.00	68.75	87.50	56.25	50.00	37.50	375.00
Cost Input	50.00	75.00	87.50	62.50	62.50	37.50	375.00
Transition	75.00	68.75	87.50	62.50	62.50	37.50	393.75

Over allocation of G&A due to transition method - $18.75

FIGURE 2b

Year 1979	Contracts Prior to 1Jan78 Non-CAS Work	 CAS Fixed Price Work	 CAS Cost Contracts	Contracts After 1Jan78 Non-CAS Work	 CAS Fixed Price Work	 CAS Cost Contracts	Total
Beginning Inventory	$100	$250	0	$ 50	$100	0	$500
Cost Input	400	600	700	500	500	300	3000
Total	$500	$850	$700	$550	$600	$300	$3500
Cost of Sales	450	650	700	150	250	300	2500
Ending Inventory	$ 50	$200	0	$400	350	0	$1000

G&A Rates.

Cost of Sales $375/$2500 = 15%

Cost Input $375/$3000 = 12.5%

G&A Allocation							
Cost of Sales	67.50	97.50	105.00	22.50	37.50	45.00	375.00
Cost Input	50.00	75.00	87.50	62.50	62.50	37.50	375.00
Transition	67.50	97.50	105.00	62.50	62.50	37.50	432.50

Over allocation of G&A due to transition method - $57.50

FIGURE 2c

Year 1980	Contracts Prior to 1Jan78 Non-CAS Work	 CAS Fixed Price Work	 CAS Cost Contracts	Contracts After 1Jan78 Non-CAS Work	 CAS Fixed Price Work	 CAS Cost Contracts	Total
Beginning Inventory	$ 50	$200	0	$400	$350	0	$1000
Cost Input	400	600	700	500	500	300	3000
Total	$450	$800	$700	$900	$850	$300	$4000
Cost of Sales	450	800	700	450	550	300	3250
Ending Inventory	$ 0	$ 0	$ 0	$450	$300	$ 0	$ 750

G&A Rates

Cost of Sales $375/$3250 = 11.5%

Cost Input $375/$3000 = 12.5%

G&A Allocation							
Cost of Sales	51.75	92.00	80.50	51.75	63.25	34.50	373.75*
Cost Input	50.00	75.00	87.50	62.50	62.50	37.50	375.00
Transition	51.75	92.00	80.50	62.50	62.50	37.50	386.75

Over allocation of G&A due to transition method - $11.75

*Due to roundoff in G&A rate

FIGURE 3a

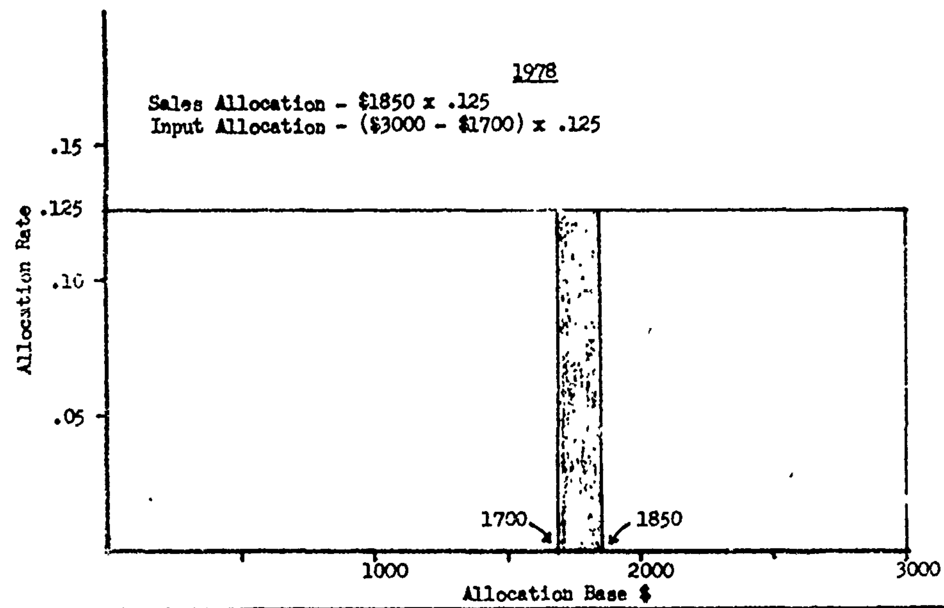
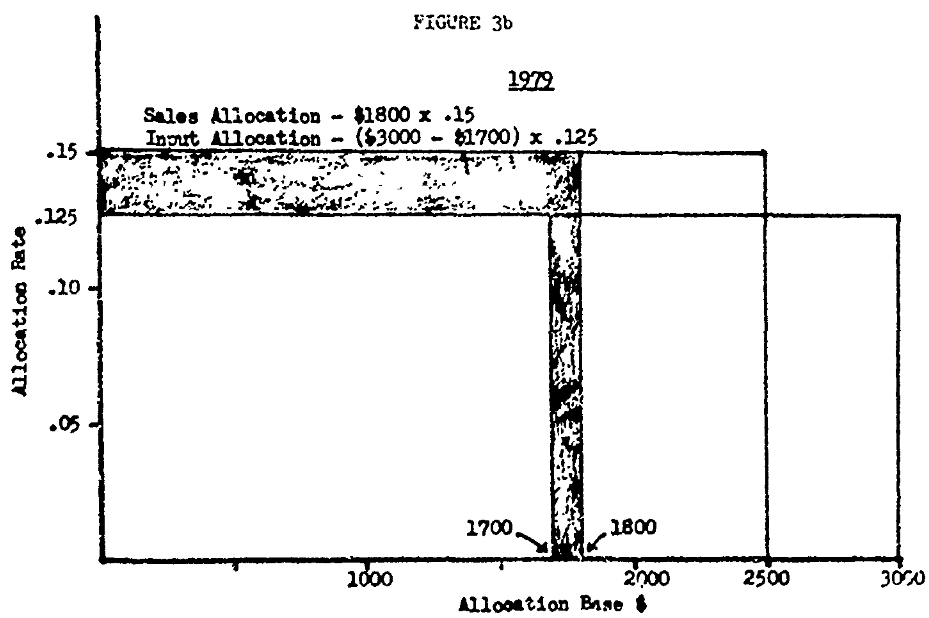


FIGURE 3b



$(\$1800 - \$1700) \times .125 = \$12.5$

plus $\$1800 \times (.15 - .125) = 45.0$

$\overline{\$57.5}$

This primative analysis does not establish a general relationship, however, since the allocation rate is itself a function of the allocation base; and inventory changes, which are the basic difference between allocation of G&A expenses on a sales or cost of sales basis and allocation of G&A expenses on a cost input basis, are not considered. In order to establish a general relationship between cost inputs, cost of sales and inventory changes which would better explain the G&A expense overallocation, it is necessary to derive a rather complicated formula. This derivation is given in Appendix A, while figure 4 summarizes the relationships developed (6).

From this formula, it is clear that the amount of G&A expenses which will be over or under allocated in a given accounting period is dependent on two main factors - the amount and direction of change in the pre and post CAS 410 inventories and the ratios of pre and post CAS 410 cost inputs to total cost input. Figure 5 provides a summary table that explains what will happen to G&A allocations under different circumstances.

ATTRIBUTION OF THE OVERALLOCATION

Given that the G&A overallocation can be precisely calculated, there is also a question of how this overallocation can be attributed to individual contracts, since each contract apparently receives an allocable share of G&A expenses in accordance with CAS 410. When contracts are viewed individually, there appears to be no problem. Costs that are allocated for estimating, accumulating and reimbursement purposes are based on expected and actual costs incurred for the accounting period. It is only when contracts are viewed collectively that the overallocation becomes apparent.

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(6) Application of this forumla to the example data in figure 2c gives an overallocation of \$12.50, which is correct. The \$1175 amount in figure 2c results from roundoff in calculating the cost of sales G&A rate. This incorrect amount was included in the example in CAS 410.

As previously discussed, the overallocation results from the interaction of inventory changes and cost inputs between pre and post CAS 410 categories of contracts. Since this is the case, the overallocation can be considered as the summation of jointly interactive component parts, i.e., the interaction of pre CAS 410 non-CAS covered contracts with post CAS 410 CAS covered contracts, etc. Since there are three types of contracts within each category, there are 3 x 3 or nine joint contributors to the total G&A overallocation. Marginal totals of this matrix for each type of contract can be interpreted as conditional amounts which can be attributed to either pre or post CAS 410 categories of contracts if it is desired to do so. The equations for this model are given in Appendix B, while figure 6 shows the results of these calculations using the prior example data.

While this attribution model is theoretically correct, it poses some practical problems in application because of constraints imposed by the nature of the contract types within the pre and post CAS 410 categories. Whereas individual elements sum to the total G&A overallocation, there are significant differences between marginal totals for CAS covered and non-CAS covered contracts. This would preclude use of this model for establishing adjustment amounts under a policy to disallow overallocated G&A expenses. The amount of an adjustment would be significantly different depending on whether pre or post CAS 410 contracts are adjusted, e.g., in 1978, attribution of the overallocation to pre CAS 410 contracts would result in an adjustment of \$5.41 to CAS covered contracts, while attribution to post CAS 410 contracts would result in an adjustment of \$11.09. This difference arises because non-CAS covered contracts are not subject to adjustment.

POLICY OPTIONS

If no action were taken by the Department of Defense, the G&A overallocations which would result from the CAS 410 transition method would result in substantial windfalls to those contractors who elected to utilize the transition method. This windfall can be characterized as either increased cash flow or overpricing. This distinction, which can be argued on both legal and accounting grounds, provides a basis for two alternative approaches for dealing with the overallocation, each of which has its peculiar advantages and disadvantages.

Based on a survey conducted by the Contract Pricing and Financial Office, Headquarters U.S. Air Force, the total estimated G&A overallocation involving five contractors (some with more than one cost center) was \$116 million over the transition period. The results

FIGURE 4

$$\text{Over/Under Allocation} = \frac{G}{CS_t}\left[\frac{CI_a\ (BI_p - EI_p) \;-\; CI_p\ (BI_a - EI_a)}{CI_t}\right]$$

Where G = Allocable G&A Expenses

CI_a = Cost Inputs of Contracts awarded after CAS 410

CI_p = Cost Inputs of Contracts awarded before CAS 410

CI_t = Total Cost Inputs $(CI_p + CI_a)$

CS_t = Total Cost of Sales

BI_p = Beginning Inventory of Contracts awarded prior to CAS 410

EI_p = Ending Inventory of Contracts awarded prior to CAS 410

BI_a = Beginning Inventory of Contracts awarded after CAS 410

EI_a = Endihg Inventory of Contracts awarded after CAS 410

FIGURE 5

EFFECT OF INVENTORY CHANGES ON G&A ALLOCATION

	$BI_p - EI_p > 0$ PRE CAS 410 INVENTORY DECREASE	$BI_p - EI_p = 0$ NO INVENTORY CHANGE	$BI_p - EI_p < 0$ PRE CAS 410 INVENTORY INCREASE
$BI_a - EI_a > 0$ POST CAS 410 INVENTORY DECREASE	DEPENDS ON MAGNITUDE OF INVENTORY CHANGE AND COST INPUT RATIOS	G&A UNDERALLOCATION	G&A UNDERALLOCATION
$BI_a - EI_a = 0$ NO INVENTORY CHANGE	G&A OVERALLOCATION	NO OVER/UNDER ALLOCATION	G&A UNDERALLOCATION
$BI_a - EI_a < 0$ POST CAS 410 INVENTORY INCREASE	G&A OVERALLOCATION	G&A OVERALLOCATION	DEPENDS ON MAGNITUDE OF INVENTORY CHANGE AND COST INPUT RATIOS

FIGURE 6

	ANC	ACF	ACC	TOTAL
PNC	5.00	5.83	2.50	13.33
PCF	.21	1.46	-.63	1.04
PCC	1.46	2.92	.00	4.37
TOTAL	6.67	10.21	1.87	13.75

YEAR 1979

	ANC	ACF	ACC	TOTAL
PNC	-8.25	6.25	.75	15.25
PCF	11.75	6.75	.75	21.25
PCC	12.25	8.75	.00	21.0
TOTAL	32.25	23.75	1.50	57.50

YEAR 1980

	ANC	ACF	ACC	TOTAL
PNC	1.73	.10	.58	2.50
PCF	5.00	2.69	2.31	10.00
PCC	1.35	-1.35	.00	.00
TOTAL	8.08	1.54	2.88	12.50

ANC - Post CAS 410 non CAS covered contracts
ACF - Post CAS 410 CAS covered fixed price contracts
ACC - Post CAS 410 CAS covered cost reimbursement contracts
PNC - Pre CAS 410 non CAS covered contracts
PCF - Pre CAS 410 CAS covered fixed price contracts
PCC - Pre CAS 410 CAS covered cost reimbursement contracts

FIGURE 7
CAS 410 G&A OVERALLOCATION SUMMARY ($ MILLIONS)

COST CENTER	1977	1978	1979	1980	1981	1982	TOTAL
A	$6.44	$14.46	$16.03	$6.63	$2.97	-	$46.53
B	-	(.19)	1.34	2.51	-	-	3.66
C	-	1.69	.58	.49	.21	$.15	3.12
D	-	2.01	(.20)	(.06)	.82	-	2.57
E	-	1.98	.46	-	-	-	2.44
F	-	18.62	3.89	7.45	91	-	30.87
G	-	5.56	7.52	6.50	6.21	1.16	26.95
	$6.44	$44.13	$29.62	$23.24	$11.12	$1.31	$116.14

FIGURE 8

CAS COVERED CONTRACTS

G&A ALLOCATIONS AND CASH FLOWS

	G&A ALLOCATIONS			G&A CASH FLOWS			
TRANSITION YR	SALES ALLOCATION	INPUT ALLOCATION	TRANSITION ALLOCATION	DO NOTHING	OPTION 1	OPTION 2	OPTION 3
1	$137.4	$137.4	$141.4	$140.6	$137.7	$130.3	$136.6
2	144.4	144.1	154.8	152.4	142.7	143.5	142.0
3	154.9	153.5	165.3	162.7	152.4	153.5	150.9
4	164.4	163.2	168.8	167.3	164.1	163.0	161.7
5	172.3	171.3	174.3	174.0	174.5	171.6	170.9
TOTAL	$773.4	$769.2	$804.4	$797.0	$771.4	$761.9	$762.1
6 (PROG PMT CARRYOVER)				7.4	1.0	7.4	7.4
TOTAL				$804.7	$772.4	$769.3	$769.5

flow advantages), effectively closed out equitable adjustment as a realistic option for most contractors. Third is the apparent lack of consideration given by the CAS Board to the interplay of the method with DOD cost principles and contract financing policy.

These concerns do not appear to have been adequately addressed by the Board prior to promulgation of the standard, even though studies at the time apparently indicated that G&A overallocations resulting from the transition method would increase DOD contract costs by about $300 million (7). Moreover, the transition method was promulgated over the strong objections of DOD, with the CAS Board emphasizing as their justification the "impact on the financial statements of affected contractors" (which was unspecified) that would occur if a transition method with essentially the same concepts were not adopted (8).

The executive Secretary of the CAS Board acknowledged, in a letter dated 31 January 1978, to the Acting Director, Cost Pricing and Finance Directorate, Office of the Under Secretary of Defense (Research & Engineering), that it was recognized that the use of the transition method results in an overallocation of G&A expenses, but stated that "the provisions of CAS 410, and the transition method, along with the proposed DOD progress payment policy will effectively implement the objectives of the (CAS) Board and provide adequate protection of the Government's interest." While this statement appears to confirm that there is a deficiency in the transition method, it is interesting that even though DOD is expected to correct the deficiency, the manner of accomplishing the correction is seen as limited to progress payment policy changes. This position effectively ruled out options 2 and 3 discussed previously. This position is, however, consistent with the Board's prior observation that DOD "should correct any existing inequity resulting from the Department's progress payment policies (9)." In summary, it is the view of the author that the CAS Board promulgated a defective transition method, charged an executive agency (DOD) with correcting the defect, and then constrained the method by which the defect is to be corrected in a manner that impacts the agency's ability to contract with private industry.

On 29 March 1978, the Deputy Under Secretary of Defense (Acquisition Policy), in a memorandum to the Services and the Defense Logistics Agency, directed that a revised progress payments clause, incorporating the provisions of option 1, as previously discussed (limiting progress payments on G&A) be effective on new contracts awarded after 31 March 1978. This has provided an undisputable procedure for dealing with G&A overallocations under CAS 410 (an affected contractor who desires prog-

(7) Minutes of CAS Board Meeting No. 48, Attachment A: Dissent by Mr. McClary, Para 8166, Cost Accounting Standards Guide, Commerce Clearing House, Inc.

(8) Ibid, Attachment B: Statement of Board Members Staats, Bevis, Mautz and Walker.

(9) Ibid

ress payments will have no alternative other than to agree to the terms of the clause). The revised clause provides that the payment procedure will not apply when the CAS 410 suspense account is less than $5 million. The revised progress payment procedures are believed to adequately correct the deficiency in the transition method, however they are extremely complex and will be difficult to administer.

APPENDIX A

I. Variables & Definitions.

BI_p - Beginning Inventory of Pre-CAS 410 Contracts

BI_a - Beginning Inventory of Post-CAS 410 Contracts

CI_p - Cost Input of Pre-CAS 410 Contracts

CI_a - Cost Input of Post CAS 410 Contracts

CS_p - Cost of Sales of Pre-CAS 410 Contracts

CS_a - Cost of Sales of Post-CAS 410 Contracts

EI_p - Ending Inventory of Pre-CAS 410 Contracts

EI_a - Ending Inventory of Post-CAS 410 Contracts

CI_t - Total Cost Input $(CI_p + CI_a)$

CS_t - Total Cost of Sales $(CS_p + CS_a)$

G - G&A Expense Pool

R_p - Cost of Sales G&A Rate (G/CS_t)

R_a - Cost Input G&A Rate (G/CI_t)

A_p - Allocation to Pre-CAS 410 Contracts $(R_p \times CS_p)$

A_a - Allocation to Post-CAS 410 Contracts $(R_a \times CI_a)$

A_t - Total G&A Allocation $(A_p + A_a)$

II. Identity.

$EI = BI + CI - CS$ or $CS = CI + BI - EI$

III. Problem.

What is the difference between G and A_t

IV. Solution.

$$A_t = A_p + A_a$$

1

$$= (R_p \times CS_p) + (R_a \times CI_a)$$

$$= \left[\frac{G}{CS_t} \times CS_p\right] + \left[\frac{G}{CI_t} \times CI_a\right]$$

$$= G\left[\frac{CS_p}{CS_t} + \frac{CI_a}{CI_t}\right]$$

After some manipulation, this becomes:

$$A_t = G\left[\frac{CS_tCI_t}{CS_tCI_t} + \frac{CS_t + CI_t - CS_aCI_t - CS_tCI_p}{CS_tCI_t}\right]$$

This relationship can be expressed as $G(1 + k)$ where k is the proportion of the G&A pool that will be over (under) allocated under the transition method. Further manipulation of $G \times k$ yields:

$$G \times k = \frac{G}{CS_t}\left[\frac{CI_a(BI_p - EI_p) - CI_p(BI_a - EI_a)}{CI_t}\right]$$

2

APPENDIX B

COMPUTATION OF ATTRIBUTION

I. Joint Elements.

Let $K = \dfrac{G}{CS_t CI_t}$

a. $ANC\text{-}PNC = K\left[CI_{anc}(BI_{pnc} - EI_{pnc}) - CI_{pnc}(BI_{anc} - EI_{anc})\right]$

b. $ANC\text{-}PCF = K\left[CI_{anc}(BI_{pcf} - EI_{pcf}) - CI_{pcf}(BI_{anc} - EI_{anc})\right]$

c. $ANC\text{-}PCC = K\left[-CI_{pcc}(BI_{anc} - EI_{anc})\right]$

d. $ACF\text{-}PNC = K\left[CI_{acf}(BI_{pnc} - EI_{pnc}) - CI_{pnc}(BI_{acf} - EI_{acf})\right]$

e. $ACF\text{-}PCF = K\left[CI_{acf}(BI_{pcf} - EI_{pcf}) - CI_{pcf}(BI_{acf} - EI_{acf})\right]$

f. $ACF\text{-}PCC = K\left[-CI_{pcc}(BI_{acf} - EI_{acf})\right]$

g. $ACC\text{-}PNC = K\left[CI_{acc}(BI_{pnc} - EI_{pnc})\right]$

h. $ACC\text{-}PCF = K\left[CI_{acc}(BI_{pcf} - EI_{pcf})\right]$

i. $ACC\text{-}PCC = 0$

II. Marginal Totals

a. $ANC = K\left[CI_{anc}(BI_p - EI_p) - CI_p(BI_{anc} - EI_{anc})\right]$

b. $ACF = K\left[CI_{acf}(BI_p - EI_p) - CI_p(BI_{acf} - EI_{acf})\right]$

c. $ACC = K\left[CI_{acc}(BI_p - EI_p)\right]$

d $PNC = K\left[CI_a(BI_{pnc} - EI_{pnc}) - CI_{pnc}(BI_a - EI_a)\right]$

e. $PCF = K\left[CI_a(BI_{pcf} - EI_{pcf}) - CI_{pcf}(BI_a - EI_a)\right]$

f. $PCC = K\left[-CI_{pcc}(BI_a - EI_a)\right]$

APPENDIX C

RU:

C410?0 13:35PST 03/27/78

TYPE DATA FILE NAME? EXAMP
TYPE OUTPUT CODE
0 - COMPLETE PRINTOUT
1 - INPUT & ALLOCATION MATRIX AND SUMMARY
2 - SUMMARY ONLY
? 0
YEAR 1978

	CONTR PRIOR TO 1JAN1978			CONTR AFTER 1JAN1978			
	NON-CAS WORK	CAS FP WORK	CAS CP WORK	NON-CAS WORK	CAS FP WORK	CAS CR WORK	TOTAL
BEGINNING INV	300	200	0	0	0	0	50
COST INPUT	400	600	700	500	500	300	300
TOTAL	700	800	700	500	500	300	350
COST OF SALES	600	550	700	450	400	300	300
ENDING INV	100	250	0	50	100	0	50

G&A RATES

COST OF SALES	\$ 375 / \$	3000	=	12.5000 %
COST INPUT	\$ 375 / \$	3000	=	12.5000 %
OPTION 3	\$ 0 / \$	0	=	13.2812 %

G&A ALLOCATION

COST OF SALES	75.00	68.75	87.50	56.25	50.00	37.50	375.0
COST INPUT	50.00	75.00	87.50	62.50	62.50	37.50	375.0
TRANSITION	75.00	68.75	87.50	62.50	62.50	37.50	393.7
OPTION 3	75.00	68.75	87.50	62.50	66.41	39.84	400.0

OVERALLOCATION OF G&A DUE TO TRANSITION - \$ 18.75
OVERALLOCATION ON CAS COVERED CONTRACTS - \$ -6.25

1

CAS COVERED CONTRACT G&A CASH FLOW

DO NOTHING OPTION

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	68.75	.00	68.75
COST INPUT ALLOC			
BI TO SALES & P/P LIO	.00	.00	.00
INPUT TO SALES	.00	50.00	50.00
INPUT TO EI (P/P)	.00	10.00	10.00
COST REIMBURSEMENTS	87.50	37.50	125.00
TOTAL	156.25	97.50	253.75

OPTION 1

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	68.75	.00	68.75
COST INPUT ALLOC			
BI TO SALES & P/P LIO	.00	.00	.00
INPUT TO SALES	.00	50.00	50.00
INPUT TO EI (P/P)	.00	.00	.00
COST REIMBURSEMENTS	87.50	37.50	125.00
TOTAL	156.25	87.50	243.75

OPTION 2

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	.00	.00	.00
COST INPUT ALLOC			
BI TO SALES & P/P LIO	.00	.00	.00
INPUT TO SALES	43.75	50.00	93.75
INPUT TO EI (P/P)	25.00	10.00	35.00
COST REIMBURSEMENTS	87.50	37.50	125.00
TOTAL	156.25	97.50	253.75

OPTION 3

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	68.75	.00	68.75
COST INPUT ALLOC			
BI TO SALES & P/P LIO	.00	.00	.00
INPUT TO SALES	.00	53.12	53.12
INPUT TO EI (P/P)	.00	10.62	10.62
COST REIMBURSEMENTS	87.50	39.84	127.34
TOTAL	156.25	103.59	259.84

2

YEAR 1979

	CONTR PRIOR TO 1JAN1979			CONTR AFTER 1JAN1979			
	NON-CAS WORK	CAS FP WORK	CAS CR WORK	NON-CAS WORK	CAS FP WORK	CAS CR WORK	TOTAL
BEGINNING INV	100	250	0	50	100	0	500
COST INPUT	400	600	700	500	500	300	3000
TOTAL	500	850	700	550	600	300	3500
COST OF SALES	450	650	700	150	250	300	2500
ENDING INV	50	200	0	400	350	0	1000

G&A RATES

COST OF SALES	$ 375	/	$ 2500	=	15.0000	%
COST INPUT	$ 375	/	$ 3000	=	12.5000	%
OPTION 3	$ 0	/	$ 0	=	7.5000	%

G&A ALLOCATION

COST OF SALES	67.50	97.50	105.00	22.50	37.50	45.00	375.00
COST INPUT	50.00	75.00	87.50	62.50	62.50	37.50	375.00
TRANSITION	67.50	97.50	105.00	62.50	62.50	37.50	432.50
OPTION 3	67.50	97.50	105.00	62.50	37.50	22.50	392.50

OVERALLOCATION OF G&A DUE TO TRANSITION - $ 57.50
OVERALLOCATION ON CAS COVERED CONTRACTS - $ 40.00

3

CAS COVERED CONTRACT G&A CASH FLOW

DO NOTHING OPTION

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	97.50	.00	97.50
COST INPUT ALLOC			
BI TO SALES & P/P LIO	.00	2.50	2.50
INPUT TO SALES	.00	18.75	18.75
INPUT TO EI (P/P)	.00	35.00	35.00
COST REIMBURSEMENTS	[illegible]	37.50	142.50
TOTAL	202.50	93.75	296.25

OPTION 1

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	97.50	.00	97.50
COST INPUT ALLOC			
BI TO SALES & P/P LIO	.00	12.50	12.50
INPUT TO SALES	.00	18.75	18.75
INPUT TO EI (P/P)	.00	15.00	15.00
COST REIMBURSEMENTS	105.00	37.50	142.50
TOTAL	202.50	83.75	286.25

OPTION 2

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	.00	.00	.00
COST INPUT ALLOC			
BI TO SALES & P/P LIO	6.25	2.50	8.75
INPUT TO SALES	50.00	18.75	68.75
INPUT TO EI (P/P)	20.00	35.00	55.00
COST REIMBURSEMENTS	87.50	37.50	125.00
TOTAL	163.75	93.75	257.50

OPTION 3

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	97.50	.00	97.50
COST INPUT ALLOC			
BI TO SALES & P/P LIO	.00	2.66	2.66
INPUT TO SALES	.00	11.25	11.25
INPUT TO EI (P/P)	.00	21.00	21.00
COST REIMBURSEMENTS	105.00	22.50	127.50
TOTAL	202.50	57.41	259.91

4

YEAR 1980

	CONTR PRIOR TO 1JAN1980			CONTR AFTER 1JAN1980			
	NON-CAS WORK	CAS FP WORK	CAS CR WORK	NON-CAS WORK	CAS FP WORK	CAS CR WORK	TOTAL
BEGINNING INV	50	200	0	400	350	0	1000
COST INPUT	400	600	700	500	500	300	3000
TOTAL	450	800	700	900	850	300	4000
COST OF SALES	450	800	700	450	550	300	3250
ENDING INV	0	0	0	450	300	0	750

G&A RATES

COST OF SALES	$ 375 / $ 3250	=	11.5385 %
COST INPUT	$ 375 / $ 3000	=	12.5000 %
OPTION 3	$ 0 / $ 0	=	11.1779 %

G&A ALLOCATION

COST OF SALES	51.92	92.31	80.77	51.92	63.46	34.62	375.00
COST INPUT	50.00	75.00	87.50	62.50	62.50	37.50	375.00
TRANSITION	51.92	92.31	80.77	62.50	62.50	37.50	387.50
OPTION 3	51.92	92.31	80.77	62.50	55.89	33.53	376.92

OVERALLOCATION OF G&A DUE TO TRANSITION - $ 12.50
OVERALLOCATION ON CAS COVERED CONTRACTS - $ 10.58

5

CAS COVERED CONTRACT G&A CASH FLOW

DO NOTHING OPTION

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	92.31	.00	92.31
COST INPUT ALLOC			
BI TO SALES & P/P LIO	.00	8.75	8.75
INPUT TO SALES	.00	25.00	25.00
INPUT TO EI (P/P)	.00	30.00	30.00
COST REIMBURSEMENTS	80.77	37.50	118.27
TOTAL	173.08	101.25	274.33

OPTION 1

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	92.31	.00	92.31
COST INPUT ALLOC			
BI TO SALES & P/P LIO	.00	28.75	28.75
INPUT TO SALES	.00	25.00	25.00
INPUT TO EI (P/P)	.00	10.00	10.00
COST REIMBURSEMENTS	80.77	37.50	118.27
TOTAL	173.08	101.25	274.33

OPTION 2

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	.00	.00	.00
COST INPUT ALLOC			
BI TO SALES & P/P LIO	5.00	8.75	13.75
INPUT TO SALES	75.00	25.00	100.00
INPUT TO EI (P/P)	.00	30.00	30.00
COST REIMBURSEMENTS	87.50	37.50	125.00
TOTAL	167.50	101.25	268.75

OPTION 3

	PRE 410 CONTRACTS	POST 410 CONTRACTS	TOTAL
COST OF SALES ALLOC	92.31	.00	92.31
COST INPUT ALLOC			
BI TO SALES & P/P LIO	.00	5.25	5.25
INPUT TO SALES	.00	22.36	22.36
INPUT TO EI (P/P)	.00	26.83	26.83
COST REIMBURSEMENTS	80.77	33.53	114.30
TOTAL	173.08	87.97	261.04

6

TOTAL G&A CASH FLOWS

	SALES ALLOC	INPUT ALLOC	TRANS ALLOC	DO NOTHING	OPTION1	OPTION2	OPTION3
1978	243.7	262.5	256.2	253.7	243.7	253.7	259.6
1979	285.0	262.5	302.5	296.2	286.2	257.5	259.9
1980	271.2	262.5	273.1	274.3	274.3	268.7	261.0
TOTAL	799.9	787.5	831.8	824.3	804.3	780.0	780.8

TOTAL G&A OVERALLOCATED	88.7
SUSPENSE ACCOUNT VALUE	25.0
UNRECOVERABLE OVERALLOCATION	63.7

USED 14.38 UNITS

7

INVESTIGATION OF IMPLEMENTATION OF DODI 7000.2 CRITERIA ON NAVY SHIPBUILDING PROJECT

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INTRODUCTION

This study was undertaken under the Office of Naval Research (ONR) program concerned with improvement of the effectiveness of the Navy's systems acquisition process. An investigation was made on the effectiveness of current Navy project management systems, and the quality of current project status reporting by the shipbuilding contractor in terms of the degree to which such information meets the Navy project management office needs.

This paper summarizes the results, conclusions and recommendations resulting from an investigation undertaken in late 1977 in connection with a Navy combatant shipbuilding project in a private shipyard.

Cost/Schedule Control Systems Criteria (C/SCSC)

The net result of continuing attempts by DOD to develop effective project management has been the evolutionary development of control systems culminating in DOD's Cost/Schedule Control System Criteria (C/SCSC) (DODI 7000.2) being currently required on all new major system acquisitions.

To date there has developed substantial controversy concerning what C/SCSC is supposed to accomplish in its application to private contractors doing business with the government. Research conducted at the Defense Systems Management School, Fort Belvoir, Virginia,[2] has concluded that: (1) contractor personnel, in general, demonstrate a better understanding and make more effective use of C/SCSC concepts than do the government recipients of the data; (2) the government program management community generally lacks effective communication regarding C/SCSC analysis; and (3) government managers are reluctant to use computer and/or operations research approaches to analyze the data provided. In summary, there is the question as to whether the data being furnished by the typical contractor's cost/schedule control system are sufficient for proper execution of government's project management responsibilities.

Critical Path Network Analysis

One of the commonly used program management tools, critical path analysis, has in one form or another, been applied to an increasing number of government and industry projects since its early use on the 1960 Navy Polaris Program. Critical path analysis is now in general use on Navy weapons, air, ship, shore installation and other projects.

If the critical path technique is to be used by Navy project management on a project where the contractor reporting is in accordance with DODI 7000.2 criteria, there is the important question of whether the contractor's cost/schedule control system alone, provides adequate data to support the critical path analysis. If not, it may be unfeasible to use the network approach or on the other hand, difficult to impose still additional data requirements on the contractor to support such use.

Investigation Objectives

The primary objective of this investigation is to evaluate implementation of a representative shipbuilding contractor's Navy-validated cost/schedule control system to determine whether the existing reporting data elements, alone, provide sufficient information to allow effective Navy use of the critical path technique for its project management purposes. The investigation is supported by conducting a critical path analysis of the shipbuilding project using only those data routinely submitted to the Navy by the contractor under C/SCSC.

A secondary objective is to identify any additional data elements which could conveniently be provided by the contractor as part of its standard C/SCSC reporting--which would significantly improve the Navy's project management information posture.

METHOD OF APPROACH

A currently underway combatant ship construction project was selected for this investigation. The "Time Now" date for the analysis was selected to be September 1, 1977, at which point the ship construction was about 15 percent complete.

Among several candidate critical path techniques, the probabilistic technique, PROMAP, was used for the investigation because:

A. PROMAP has been used earlier, in connection with construction of the Lead Ship of this class and the investigative staff had pertinent prior experience and data.

B. PROMAP project schedule, resource and cost performance statistics in formats facilitate direct comparison between PROMAP analysis results and the contractor C/SCSC report data.

C. PROMAP is unique in its ability to account for project uncertainties[3] and their effects on shipbuilding schedule, costs and resource requirements.

SOURCE DATA FOR INVESTIGATION

The contractor-furnished data were obtained largely from two periodically submitted reports, Material Order Schedule and Job Status Report, which provide:

A. Identification of the Work Orders (which are used as the "activity" elements of the PROMAP network)

B. Work Order scheduled start/finish dates

C. Budgeted manhours for each Work Order, by craft

D. Projected total manhours for each Work Order not yet completed

E. Percentage complete for each Work Order underway at the report date

F. Scheduled delivery dates for materials and specification items

Because the contractor is not required to submit a critical path network as part of his data submittals (nor did the contractor maintain a network plan as part of his internal management system), precedence logic for the activities (Work Orders) of the critical path network were initially developed by the investigative staff.

Later, prior to completion of the investigation, the contractor developed its own critical path network, but it was structured at a grosser level of detail than the Work Order level.

RESULTS

The results of the investigative PROMAP analysis are as follows:

Critical Path Network

The critical path network developed by the investigative staff represents the project plan as of 9/1/77 and is based on the Work Orders identified in the contractor's Job Status Report dated 8/28/77, which contains significant detail primarily on hull erection Work Orders prior to Launch. Preoutfitting, outfitting, test and evaluation and other post-launch Work Orders are represented in gross detail because of the lack of detail data on unreleased Work Orders.

Schedule Risk Analysis

Because the contractor did not report on Work Order labor requirements by craft, beyond a 60-day period, it was assumed that adequate labor resources would be made available by the contractor to perform the work in accordance with the schedule dates shown in the Job Status Report. Accordingly, no attempt was made to determine whether such resources were in fact available and, if not, the extent of any resulting schedule slippages.

Two analyses were run: Baseline Analysis utilizing the data on current budget baseline and Actual Cost Analysis utilizing data on actual work progress as reported in the contractor's Job Status Report--by item.

Baseline Analysis (See Figure 1) indicates that there is a 28 percent probability of attainment of the hull Launch by the scheduled date, October 14, 1978. The analysis also indicates that the scheduled performance should be accelerated by 12 workdays to realize a 50 percent probability of meeting the scheduled Launch date. Correspondingly, if it is [illegible] ired to attain a 90 percent probabil[illegible]y of Launch by the schedule date, shipwork would have to be accelerated by 31 workdays.

The 12 days difference between the contractor's scheduled Launch date and the PROMAP "50 percent" date is primarily due to the "merger bias" which is the schedule impact of project uncertainties[1] accounted for by the probabilistic analysis.

As compared with the Baseline Analysis results, the Actual Cost Analysis (See Figure 2) shows that the probability of meeting the scheduled Launch date is reduced

from 28 to 22 percent. To realize a 50 percent probability of meeting the Launch schedule, shipwork must be accelerated by 13 workdays; to realize a 90 percent probability, the acceleration must be 33 workdays.

Work Order Criticality Analysis

Because PROMAP accounts for work performance variability, it is able to report on the "criticality"* of each Work Order (in contrast with deterministic critical path techniques which identifies only a single critical path).

TABLE I

ACTIVITY CRITICALITY: BASELINE ANALYSIS

Code	Description	Criticality (%)
Milestone 20	Launch FFG-9	100
A002	Procure Reduction Gear	48
LOAD002	Load Reduction Gear	48
243-01C	Mach Shaft Bearing & Boring	46
150-53C	Erect Dk Hse Str Unit 5-3	44
195-33B	Erect On Ways Unit 3-3	44
A001	Procure Main Gas Turbines	42
LOAD001	Load Main Gas Turbines	42
245-02	Ins Prop Hub Pk/Secure	24
150-52C	Erect Dk Hse Str Unit 5-2	24
195-34B	Erect On Ways Unit 3-4	20

The corresponding criticality values for Actual Cost Analysis, shown in TABLE II, below, reveal only minor differences.

* Criticality is defined as the probability that a given Work Order will lie on the critical path during the course of the project. Criticality is a convenient measure of the "sensitivity" -- or importance -- of an individual Work Order.

TABLE II

CRITICALITY REPORT: ACTUAL COST ANALYSIS

Code	Description	Criticality (%)
Milestone 20	Launch FFG-9	100
A002	Procure Reduction Gears (GFE)	52
LOAD002	Load Reduction Gear	52
243-01C	Mach Shaft Bearing & Boring	52
A001	Procure Main Gas Turbines (GFE)	42
LOAD001	Load Main Gas Turbines	42
150-53C	Erect Dk Hse Str Unit 5-3	42
195-33B	Erect On Ways Unit 3-3	42
245-02	Ins Prop Hub Pk/Secure	26
150-52C	Erect Dk Hse Str Unit 5-2	22
195-34B	Erect On Ways Unit 3-4	20

Production Labor Analysis

PROMAP presents labor requirement statistics for any individual craft or combinations of crafts, as desired. Because contractor labor pool data was not made available, it was necessary to assume that sufficient labor is on hand to meet demand, in order to avoid "levelling" of the work load due to manpower constraints.

The PROMAP Baseline Analysis expected total resource utilization of 2,067,254 manhours closely matches the budgeted 2,067,818 manhours shown in the contractor's Job Status Report while the Actual Cost Analysis projected total of 2,188,142 manhours compares favorably with the contractor's projected 2,117,437 manhours.

As shown in Figure 3, a peak daily Baseline requirement for 592 workers occurred during the two-week period ending 10/21/77; dropping off rapidly so that by the end of February 1978 only about 400 workers-per-day are required.

For the same two week period, the Actual Cost Analysis (Figure 4) indicates an actual peak labor requirement of 670 workers-per-day, or a 13.3 percent increase over the Baseline peak requirement.

Budgeted Cost for Work Scheduled (BCWS)

BCWS is the budget applicable to the labor scheduled to be accomplished within a given time frame. As shown in Figure 5, the cumulative BCWS expected value at "Time Now" is interpolated to be $7.28 million; at project completion, $28.50 million. The minimum and maximum values of $27.87 million and $29.01 million respectively, reflect the variability of project performance.

Budgeted Cost for Work Performed (BCWP)

BCWP is the budget applicable to the work actually accomplished. The BCWP tabulation of Figure 6, is based on the percentage completion estimates for underway activities contained in the contractor's Job Status Report (8/29/77). The value of BCWP at "Time Now" is interpolated to be $6.8 million.

Actual Cost for Work Performed (ACWP)

ACWP is the "Time Now" value of the actual accumulated hours spent on Work Order line items. As shown in Figure 7, the ACWP at "Time Now" is interpolated to be $7.1 million.

Schedule Variance Analysis

The difference between BCWS and BCWP values provides a schedule variance in terms of dollars. In the FFG-9 case, less work was performed by "Time Now" than was scheduled to be done by that time and the resulting schedule variance is $0.48 million, which indicates a schedule variance in terms of time, equal to 9 workdays.

Cost Variance Analysis

The difference between the BCWP and ACWP values at "Time Now" provides a cost variance between the actual cost of work performed to date and the budgeted cost for that work. The cost variance amounts to $0.3 million, with "actual" cost exceeding "budget" cost.

Estimated Cost at Completion (ECAC)

ECAC is the cumulative total of the projected cost at completion of all Work Order items as shown in Figure 7. The Expected Value for ECAC is $30.18 million with minimum and maximum values of $29.63 million and $30.58 million, respectively, resulting from variability of project performance.

FINDINGS

The investigation resulted in a number of findings, both general and specific:

General

The routine data submittals resulting from the contractor's validated cost/schedule control system constitute a marginally adequate data base to support a Navy-maintained critical path network-based project monitoring and control system.

The contractor's cost/schedule control system does not provide adequate data upon which to base a meaningful "forward look" which in a predictive manner may be used to:

(a) Identify potential problems

(b) Evaluate contractor's work load and work force planning

(c) Evaluate cost/schedule impacts of change orders or other contract changes.

The contractor's use of a "deterministic" (as opposed to "probabilistic") scheduling approach results in schedules which are inherently optimistic.

There is no available indication of the nature of the contractor's estimating philosophy which provides the basis for his scheduling, costing and resource allocation. For example, were estimates "best," "most likely," "expected" values, or other deterministic values? Or did the contractor obtain three values, "optimistic," "pessimistic," and "most likely" and then calculate an "expected" value. Without such indication, it is difficult to determine whether the inputs to the contractor's cost/schedule control system are biased in one direction or another (or, for that matter, whether the Navy's independent estimating for progressing purposes, is similarly biased).

Although the contractor's Monthly Job Status Report and other submittals identify all of the Work Orders, the absence of any contractor-furnished critical path network or other Work Order sequence display makes it difficult to define the logical predecessor-successor relationships of the Work Orders. This deficiency is especially critical when considering equipment procurement and subsequent installation schedule pairs. Accordingly, it is difficult to determine the identity of the Work Orders which have some level of criticality and therefore require particular Navy management attention.

Work Order duration data do not accompany the schedules shown in the Monthly Job Status Report, which makes it difficult to interpret the significance of the Work Order scheduled start and finish dates. For example, the contractor informed the investigative staff that the "start" date represents the "earliest start date" and the "finish" date represents the "latest allowable finish date" for a Work Order. If such is the case, then the contractor's scheduling approach has fully allocated all available "float." In other words, all the Work Orders are 100 percent "critical."

Many Work Order schedules shown on the Job Status Report are not compatible with the progressing information shown thereon. In some instances, Work Orders which should have been completed prior to the "Time Now" date of the report are still underway, or have not yet been started. In many such cases, the schedule dates are supposed to be annotated with the letter "L" along-side, denoting lateness; however, in a number of instances, such a notation does not appear.

The contractor releases Work Orders to the performing activities 60 days prior to the scheduled start date of the work. Accordingly, there are no Job Status Report details on Work Orders scheduled to be released beyond the 60-day period. Such information may be available in preliminary form somewhere in the contractor's validated control system, but is not currently being required by the Navy to be furnished as part of the contractor's routine data submittals. It is concluded that such data is not required because the Navy is not employing a rigorous project management tool which can employ such data. This deficiency seriously handicaps any "forward look" analysis of the impact of changes, late deliveries or any other "perturbations" to the project plan.

The different contractor C/SCSC reporting documents are to some extent updated by the contractor independently of each other, without suitable cross-checking interfaces, resulting in significant conflicts in data. For example, the latest material delivery schedule made available for the purposes of this investigation represent data several months old and, hence, not compatible with the current contractor-released installation schedules. Such scheduling inconsistencies became readily visible during the structuring of the PROMAP critical path network which requires precise interfaces between interdependent Work Orders.

The GFE/GFM schedule provided to us by the Navy represented contractual delivery dates, not necessarily predicted delivery dates on an item-by-item basis. It is suspected that Navy tracking of GFE/GFM is not sufficiently responsive which if the case, can lead to potential contractor delays and disruptions resulting from late deliveries.

Specific

The process of subjecting the Work Orders to the level of analytical scrutiny required to develop the critical path network revealed at least one serious error in the sequencing of hull erection tasks implied by the contractor schedules: The upper units of the hull above the auxiliary machine rooms were scheduled to be erected earlier than the scheduled date for installing the diesel generators in the auxiliary machinery rooms, immediately below.

The Navy apparently does not currently have routine access to a record of actual start and finish dates for all Work Orders, nor does the contractor routinely reschedule activities which were due to start or finish by the "Time Now" date but have not actually done so.

Approximately 300 Work Orders were found which should have been rescheduled; 200 of which were items that (according to the original schedule) should have started before "Time Now," but did not.

RECOMMENDATIONS

Based on the results of this investigation, it is recommended that the DODI 7000.2 criteria as applied to Navy shipbuilding project management be supplemented to incorporate the following additional procedures and requirements for information to be furnished by a contractor's management information system.

Within 30 days following award of a shipbuilding contract, the contractor should be required to deliver an "as planned" activity network project plan, identifying the planned work packages and the interdependency sequences which the contractor intends to follow in order to meet his contractual commitments. The "as planned" project plan need not be regarded as a commitment as to the precise manner in which the job eventually will be done, but should be provided primarily to:

(1) Assure the Navy that the contractor has conducted adequate planning, scheduling and resource allocation for proper execution of the project.

(2) Provide the Navy with an important assist in interpreting and rationalizing the large amount of data otherwise furnished by the contractor under DODI 7000.2 criteria.

Using the contractor's initial project plan (6.1 above) as a starting framework, the Navy should utilize critical path analysis as a continuing element of its administration of the project. The critical path network should be maintained and updated to incorporate all contractor construction, procurement, outfitting, test, evaluation and other actions required to successfully complete the project. In addition, GFE/GFM delivery cycles should be interfaced with the project plan and continually monitored and evaluated regarding impact of GFE/GFM deliveries on contractor performance. Upon completion of the project, the individual updates of the maintained critical path network, together with the final, "as built" network, will provide a useful documentation package for post-project analysis or for claims evaluation purposes.

The Navy should require early submittal of sufficient detailed information on all contractor Work Orders to allow effective Navy monitoring of the planned project from start to completion. To allow for the preliminary nature of the details on Work Orders that are scheduled considerably beyond "Time Now," the Navy should acknowledge that any advance detail data submitted on Work Orders are preliminary--and will be used for Navy planning purposes, only.

The Navy should require that contractor data submittals concerning schedules incorporate specific data on Float, Slack, Criticality, or other measure of the relative importance of each of the Work Orders to overall attainment of contractual commitments.

The Navy should require the contractor to routinely submit a productive labor comparison by month, comparing available labor resources with the level required to meet delivery commitments. The Navy should then compare such data with its own independently developed data for the purpose of evaluating the adequacy of the contractor's resource planning.

Where project uncertainty is a significant factor, Navy shipbuilding project management should use a probabilistic critical path networking technique with which to independently generate BCWP, BCWS and ECAC data which can directly be compared with contractor data submittals.

REFERENCES

1. Feiler, A. M. "Project Risk Management," XXIII International Meeting of the Institute of Management Science, Athens, Greece, 27 July 1977.

2. Holeman, F. B., Jr. "C/SCSC Analysis: The Time is Now," Defense Management Journal. April 1974, pp. 39-42.

3. Mapella, Leonard S. "The Effect of the Cost/Schedule Control System Criteria (C/SCSC) on Contractor Planning and Control." Unpublished Doctoral Dissertation, George Washington University, 1973.

4. Varley, T. C. "CBD Announcement, ONR Systems Acquisition Research and Technology," ONR:431, 17 June 1977.

LIST OF FIGURES

LIST OF TABLES

PROJECT *BASELINE ANALYSIS UPDATE TO 01 SEP 77 RUN MLIA

SCHEDULE RISK REPORT (LISTED ACCORDING TO APPROVED SCHEDULE DATE)

(*, APPROVED SCHEDULE DATE : B = ACTIVITY BEGINNING DATE, C = ACTIVITY COMPLETION DATE, M = MILESTONE DATE)
(** + (SURPLUS) = THE DATE OF MEETING ACCEPTABLE RISK LEVEL IS (EARLIER) THAN APPROVED SCHEDULE DATE
- (DEFICIT) = THE DATE OF MEETING ACCEPTABLE RISK LEVEL IS (LATER) THAN APPROVED SCHEDULE DATE)

ACTIVITY / MILESTONE CODE	DESCRIPTION	PERCENT CRITI-CALITY	LEAD RESPONS-IBILITY		APPROVED SCHEDULE* DATE	PROB OF MEETING DATE		ACCEPTABLE RISK LEVEL		DATE OF MEETING LEVEL	DEFICIT** OR SURPLUS (WORK-DAYS)
MIL001	START LOFTING	0	MILESTN	(M)	2AUG76	100	P	10	P	2AUG76	0
MIL001	**	0	MILESTN	(M)	2AUG76	100	P	50	P	2AUG76	0
MIL002	START PREPARATION	0	MILESTN	(M)	3JAN77	100	P	10	P	3JAN77	0
MIL002	**	0	MILESTN	(M)	3JAN77	100	P	50	P	3JAN77	0
MIL003	START STRUCT. SUB-ASSY HULL UNITS	0	MILESTN	(M)	24JAN77	100	P	10	P	24JAN77	0
MIL003	**	0	MILESTN	(M)	24JAN77	100	P	50	P	24JAN77	0
MIL004	START FABRICATION	0	MILESTN	(M)	14FEB77	100	P	10	P	14FEB77	0
MIL004	**	0	MILESTN	(M)	14FEB77	100	P	50	P	14FEB77	0
MIL005	START FAB INTAKE UPG SYS & MACHY FNDNS	0	MILESTN	(M)	14FEB77	100	P	10	P	14FEB77	0
MIL005	**	0	MILESTN	(M)	14FEB77	100	P	50	P	14FEB77	0
MIL006	START ASSY HULL UNITS	0	MILESTN	(M)	14FEB77	100	P	10	P	14FEB77	0
MIL006	**	0	MILESTN	(M)	14FEB77	100	P	50	P	14FEB77	0
MIL007	START INSTL'N OF MACHY FNDNS	0	MILESTN	(M)	14FEB77	100	P	10	P	14FEB77	0
MIL007	**	0	MILESTN	(M)	14FEB77	100	P	50	P	14FEB77	0
MIL010	START INSTL'N GT & RED GR FNDNS	0	MILESTN	(M)	14MAR77	100	P	10	P	14MAR77	0
MIL010	**	0	MILESTN	(M)	14MAR77	100	P	50	P	14MAR77	0
MIL008	START PLATEN OUTFITTING - ELEC/HVAC	0	MILESTN	(M)	31MAY77	100	P	10	P	31MAY77	0
MIL008	**	0	MILESTN	(M)	31MAY77	100	P	50	P	31MAY77	0
MIL009	LAY KEEL	0	MILESTN	(M)	11JUL77	100	P	10	P	11JUL77	0
MIL009	**	0	MILESTN	(M)	11JUL77	100	P	50	P	11JUL77	0
MIL011	COMPL PREP. MAJOR HULL UNITS	0	MILESTN	(M)	30SEP77	0	P	10	P	17NOV77	- 33
MIL011	**	0	MILESTN	(M)	30SEP77	0	P	50	P	8NOV77	- 26
MIL012	START ERECTION OF SUPERSTRUCTURE	0	MILESTN	(M)	15MAY78	100	P	10	P	15MAY78	0
MIL012	**	0	MILESTN	(M)	15MAY78	100	P	50	P	15MAY78	0
MIL013	LOAD SHIP SVCE DSL	0	MILESTN	(M)	3JUL78	48	P	10	P	9AUG78	- 26
MIL013	**	0	MILESTN	(M)	3JUL78	48	P	36	P	6JUL78	- 2
MIL014A	LOAD GAS TURBINE	62	MILESTN	(M)	8JUL78	60	P	10	P	18AUG78	- 32
MIL014A	**	62	MILESTN	(M)	8JUL78	60	P	50	P	7JUL78	- 2
MIL014B	LOAD REDUCTION GEAR	48	MILESTN	(M)	8JUL78	48	P	10	P	7AUG78	- 23
MIL014B	**	48	MILESTN	(M)	8JUL78	48	P	50	P	7JUL78	- 2
MIL015	START BORING SHAFT	46	MILESTN	(M)	7AUG78	46	P	10	P	8SEP78	- 23
MIL015	**	46	MILESTN	(M)	7AUG78	46	P	50	P	8AUG78	- 1
MIL016	INSTLL SHAFTING & PROPLLR HUB	24	MILESTN	(M)	11SEP78	50	P	10	P	11OCT78	- 22
MIL016	**	24	MILESTN	(M)	11SEP78	50	P	50	P	11SEP78	0
MIL017	INSTLL RUDDER	0	MILESTN	(M)	26SEP78	100	P	10	P	26SEP78	0
MIL017	**	0	MILESTN	(M)	26SEP78	100	P	50	P	26SEP78	0
MIL018	COMPLTE HULL ASSY	44	MILESTN	(M)	6OCT78	22	P	10	P	30NOV78	- 38
MIL018	**	44	MILESTN	(M)	6OCT78	22	P	50	P	18OCT78	- 8
MIL019	COMPLTE PRE-LAUNCH TANK TESTING	3	MILESTN	(M)	11OCT78	100	P	10	P	18JUL78	+ 60
MIL019	**	0	MILESTN	(M)	11OCT78	100	P	50	P	23JUN78	+ 76
MIL020	LAUNCH FFG	100	MILESTN	(M)	16OCT78	30	P	10	P	30NOV78	- 31
MIL020	**	100	MILESTN	(M)	16OCT78	26	P	89	P	31OCT78	- 12

Figure 1. Schedule Risk Report, Baseline Run.

PROJECT ACTUAL COST ANALYSIS UPDATE TO 21 SEP 77 HK24

SCHEDULE RISK REPORT (LISTED ACCORDING TO APPROVED SCHEDULE DATE)

(* APPROVED SCHEDULE DATE ; B = ACTIVITY BEGINNING DATE, C = ACTIVITY COMPLETION, ETC., M = MILESTONE DATE)
(** + (SURPLUS) = THE DATE OF MEETING ACCEPTANCE RISK LEVEL IS (EARLIER) THAN APPROVED SCHEDULE DATE
- (DEFICIT) = THE DATE OF MEETING ACCEPTANCE RISK LEVEL IS (LATER) THAN APPROVED SCHEDULE DATE)

ACTIVITY / MILESTONE CODE	DESCRIPTION	PERCENT CRITI-CALITY	LEAD RESPONS-IBILITY	APPROVED SCHEDULE * DATE	PROB OF MEETING DATE	ACCEPTABLE RISK LEVEL	DATE OF MEETING LEVEL	** DEFICIT OR SURPLUS (WORK-DAYS)
MILE01	START LOFTING	0	MILESTN (M)	2AUG76	100 P	10 P	2AUG76	0
MILE01	..	0	MILESTN (M)	2AUG76	100 P	50 P	2AUG76	0
MILE02	START PREPARATION	0	MILESTN (M)	3JAN77	100 P	10 P	3JAN77	0
MILE02	..	0	MILESTN (M)	3JAN77	100 P	50 P	3JAN77	0
MILE03	START STRUCT. SUB-ASSY HULL UNITS	0	MILESTN (M)	24JAN77	100 P	10 P	24JAN77	0
MILE03	..	0	MILESTN (M)	24JAN77	100 P	50 P	24JAN77	0
MILE04	START FABRICATION	0	MILESTN (M)	14FEB77	100 P	10 P	14FEB77	0
MILE04	..	0	MILESTN (M)	14FEB77	100 P	50 P	14FEB77	0
MILE05	START FAB INTAKE PPG SYS & MACHY FNDNS	0	MILESTN (M)	14FEB77	100 P	10 P	14FEB77	0
MILE05	..	0	MILESTN (M)	14FEB77	100 P	50 P	14FEB77	0
MILE06	START ASSY HULL UNITS	0	MILESTN (M)	14FEB77	100 P	10 P	14FEB77	0
MILE06	..	0	MILESTN (M)	14FEB77	100 P	50 P	14FEB77	0
MILE07	START INSTL'N OF MACHY FNDNS	0	MILESTN (M)	14FEB77	100 P	10 P	14FEB77	0
MILE07	..	0	MILESTN (M)	14FEB77	100 P	50 P	14FEB77	0
MILE10	START INSTL'N GT & RED GR FNDNS	0	MILESTN (M)	14MAR77	100 P	10 P	14MAR77	0
MILE10	..	0	MILESTN (M)	14MAR77	100 P	50 P	14MAR77	0
MILE08	START PLATEN OUTFITTING - ELEC/HVAC	0	MILESTN (M)	31MAY77	100 P	10 P	31MAY77	0
MILE08	..	0	MILESTN (M)	31MAY77	100 P	50 P	31MAY77	0
MILE09	LAY KEEL	0	MILESTN (M)	11JUL77	100 P	10 P	11JUL77	0
MILE09	..	0	MILESTN (M)	11JUL77	100 P	50 P	11JUL77	0
MILE11	COMPL PREP. MAJOR HULL UNITS	0	MILESTN (M)	30SEP77	0 P	10 P	18NOV77	- 32
MILE11	..	0	MILESTN (M)	30SEP77	0 P	50 P	8NOV77	- 26
MILE12	START ERECTION OF SUPERSTRUCTURE	0	MILESTN (M)	15MAY78	100 P	10 P	15MAY78	0
MILE12	..	0	MILESTN (M)	15MAY78	100 P	50 P	15MAY78	0
MILE13	LOAD SHIP SVCE DSL	0	MILESTN (M)	3JUL78	55 P	10 P	7AUG78	- 26
MILE13	..	0	MILESTN (M)	3JUL78	55 P	50 P	3JUL78	0
MILE14A	LOAD GAS TURBINE	42	MILESTN (M)	5JUL78	39 P	10 P	10AUG78	- 26
MILE14A	..	42	MILESTN (M)	5JUL78	39 P	50 P	14JUL78	- 7
MILE14B	LOAD REDUCTION GEAR	52	MILESTN (M)	5JUL78	49 P	10 P	25AUG78	- 37
MILE14B	..	52	MILESTN (M)	5JUL78	49 P	50 P	6JUL78	- 1
MILE15	START BORING SHAFT	52	MILESTN (M)	7AUG78	44 P	10 P	27SEP78	- 36
MILE15	..	52	MILESTN (M)	7AUG78	44 P	50 P	9AUG78	- 2
MILE16	INSTLL SHAFTING & PROPELLR HUB	26	MILESTN (M)	11SEP78	45 P	10 P	31OCT78	- 36
MILE16	..	26	MILESTN (M)	11SEP78	45 P	50 P	12SEP78	- 1
MILE17	INSTLL RUDDER	0	MILESTN (M)	26SEP78	100 P	10 P	26SEP78	0
MILE17	..	0	MILESTN (M)	26SEP78	100 P	50 P	26SEP78	0
MILE18	COMPLTE HULL ASSY	42	MILESTN (M)	6OCT78	20 P	10 P	30NOV78	- 38
MILE18	..	42	MILESTN (M)	6OCT78	20 P	50 P	27OCT78	- 15
MILE19	COMPLTE PRE-LAUNCH TANK TESTING	0	MILESTN (M)	11OCT78	100 P	10 P	7SEP78	+ 24
MILE19	..	0	MILESTN (M)	11OCT78	100 P	50 P	18AUG78	+ 43
MILE20	LAUNCH [illegible]	100	MILESTN (M)	14OCT78	22 P	10 P	6DEC78	- 37
MILE20	..	100	MILESTN (M)	14OCT78	22 P	50 P	1NOV78	- 13

Figure 2. Schedule Risk Report, Actual Cost Analysis.

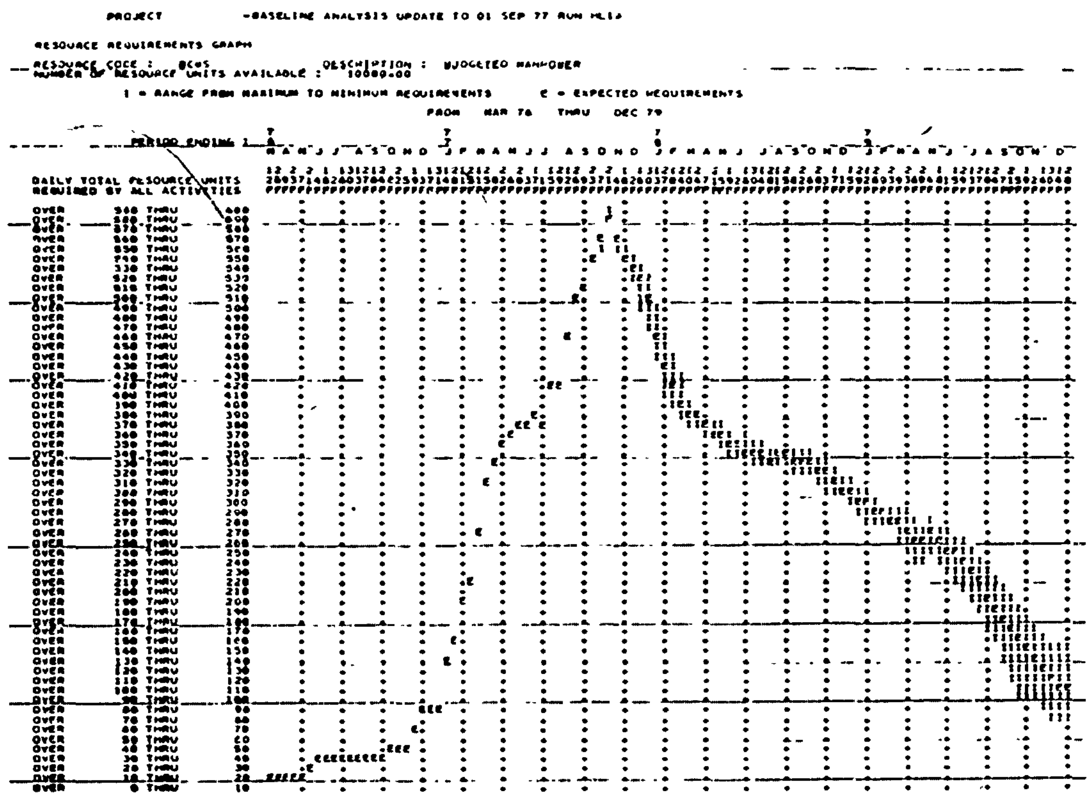

Figure 3. Resource Requirements Graph, Baseline Run.

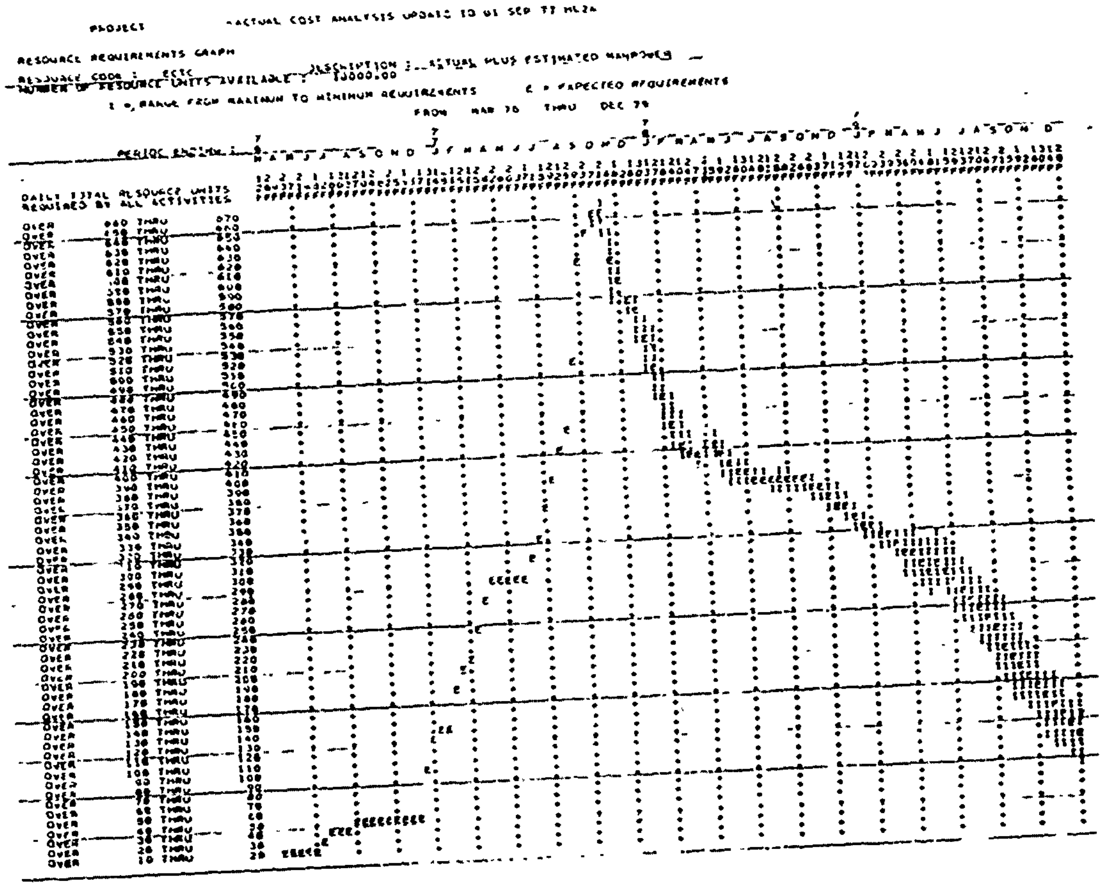

Figure 4. Resource Requirements Graph, Actual Cost Analysis.

PROJECT -BASELINE ANALYSIS UPDATE TO 01 SEP 77 RUN ML1A

AGGREGATE RESOURCE HISTORY

BUDGETED COST FOR WORK SCHEDULED (BCWS) ($1000'S)

RESOURCE CODES : BCWS DESCRIPTION : BUDGETED MANPOWER

TIME PERIOD = 2 WEEK(S)

PERIOD ENDING	NET PER TIME PERIOD (DOLLARS) (MIN)	(EXPECTED)	(MAX)	CUMULATIVE NET (DOLLARS) (MIN)	(EXPECTED)	(MAX)
12 MAR 76	15	15	15	15	15	15
26 MAR 76	15	15	15	30	30	30
9 APR 76	15	15	15	45	45	45
23 APR 76	15	15	15	60	60	60
7 MAY 76	18	18	18	78	78	78
21 MAY 76	29	29	29	106	106	106
4 JUN 76	34	34	34	141	141	141
....	...	...	...	...	...	...
26 AUG 77	554	556	556	7080	7080	7080
9 SEP 77	512	513	515	7592	7593	7595
23 SEP 77	602	604	606	8194	8197	8200
7 OCT 77	616	622	627	8813	8819	8826
...	...	...	...	...	...	..
16 MAY 80	0	16	37	27855	28463	28967
30 MAY 80	0	10	30	27858	28473	28978
13 JUN 80	0	9	30	27862	28482	28996
27 JUN 80	0	7	19	27865	28489	29012
11 JUL 80	0	5	16	27868	28494	29013
25 JUL 80	0	6	15	27871	28498	29013
8 AUG 80	0	1	9	27871	28500	29014
22 AUG 80	0	1	9	27871	28501	29014
5 SEP 80	0	1	7	27871	28502	29014
19 SEP 80	0	1	7	27871	28502	29014
3 OCT 80	0	1	6	27871	28503	29014
17 OCT 80	0	0	0	27871	28503	29014

Figure 5. Budgeted Cost For Work Scheduled (BCWS) History, Baseline Run.

PROJECT LAS-ACTUAL COST ANALYSIS UPDATE TO 01 SEP 77 ML2A

AGGREGATE RESOURCE HISTORY (CONTINUED)

BUDGETED COST FOR WORK PERFORMED (BCWP) ($1000'S)

TIME PERIOD = 2 WEEK(S)

PERIOD ENDING	NET PER TIME PERIOD (DOLLARS) (MIN)	(EXPECTED)	(MAX)	CUMULATIVE NET (DOLLARS) (MIN)	(EXPECTED)	(MAX)
15 JUL 77	356	356	356	8081	8081	8081
29 JUL 77	427	427	427	8517	8517	8517
12 AUG 77	458	458	458	8978	8978	8975
26 AUG 77	539	539	539	6814	6814	6519

Figure 6. Budgeted Cost For Work Performed (BCWP) History, Actual Cost Analysis.

PROJECT ACTUAL COST ANALYSIS UPDATE TO 01 SEP 77 ML2A

AGGREGATE RESOURCE HISTORY (CONTINUED)

ACTUAL PLUS PROJECTED COSTS ($1000'S)

TIME PERIOD = 2 WEEK(S)

PERIOD ENDING	NET PER TIME PERIOD (DOLLARS) (MIN)	(EXPECTED)	(MAX)	CUMULATIVE NET (DOLLARS) (MIN)	(EXPECTED)	(MAX)
15 JUL 77	302	302	302	5336	5336	5336
27 JUL 77	454	454	454	5790	5790	5790
12 AUG 77	483	483	483	6273	6273	6273
26 AUG 77	559	559	559	6832	6832	6832
9 SEP 77	596	597	598	7428	7429	7430
23 SEP 77	699	701	703	8127	8130	8134
7 OCT 77	712	720	727	8841	8850	8859
....	...	...	...	..	...	..
16 MAY 80	1	15	32	29822	30133	30462
30 MAY 80	0	10	24	29827	30163	30495
13 JUN 80	0	9	27	29529	30152	30544
27 JUN 80	0	7	27	29530	30160	30569
11 JUL 80	0	6	24	29610	30169	30573
25 JUL 80	0	5	17	29610	30170	30576
8 AUG 80	0	2	17	29630	30172	30578
22 AUG 80	0	2	12	29630	30174	30576
5 SEP 80	0	1	9	29630	30175	30576
19 SEP 80	0	1	9	29630	30177	30574
3 OCT 80	0	1	7	29630	30178	30575
17 OCT 80	0	0	0	29630	30178	30576

Figure 7. Actual Plus Project Cost History, Actual Cost Analysis.

REPLACEMENT COST ACCOUNTING: ITS POSSIBLE EFFECTS ON GOVERNMENT CONTRACTS

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ABSTRACT

A recent development in the accounting profession--replacement cost accounting--could have a major impact on government procurement contracts. Replacement cost accounting, i.e., the restatement of the balance sheet and income statement to reflect the effects inflation has had on corporate assets--could lead manufacturers to overcompensate in overhead rates and cost of goods sold to make up for the underdepreciation of assets and the underpricing of inventories in comparison to today's costs. This paper will explain what replacement cost accounting is and its possible ramifications for government contracts in accounting for depreciation and cost of goods sold.

PART I

THE WHY OF REPLACEMENT COST ACCOUNTING

Financial statements based on historical costs are used by many different people. Managers use information from financial statements to improve their business decisions. Investors use information from financial statements in deciding where to invest and in evaluating the success of their investments. Lenders use information from financial statements to decide whether to grant loans and what conditions to require. The U. S. government in general and the U. S. Air Force in particular use financial statements in evaluating various procurement actions. These statements are used to evaluate a contractor's financial position and operating performance to determine if a contract should be let, continued, or cancelled.

If there were no changes in the purchasing power of money and no changes in the prices of individual items, historical cost accounting would serve all users of financial statements just fine. Assets and liabilities measured at historical costs would reveal the financial position of the firm, and historical costs matched against revenues of a current period would provide a useful measurement of current performance. The past and present measurements of a contractor's performance could be evaluated on the same basis without having to worry about restating past results to reflect current prices. Unfortunately, life is not that simple.

In recent years, almost all nations of the world have experienced significant inflation. The price changes that have occurred have made financial statements based on historical costs useful as a source of information for decision making and for evaluating past performance in light of today's activities. Simply stated, historical costs do not adequately segregate true operating profits from the costs of sustaining the business during periods of changing price levels. For example, historical cost financial statements tend to overstate profits during periods of rising prices by understating expense. They match current revenues with dated costs and fail to recognize the eroding purchasing power of the dollar. Specifically, plant capacity or equipment purchased in earlier periods becomes "undervalued" in financial statements during periods of inflation. If inventories are held over long periods of time, they too are shown at less than their current value. When the historical costs of these assets are "matched" with revenues to measure income, the "income" will include the effects of both specific price changes and general inflation and may not really show how well the contractor has performed. Therefore, in inflationary times, financial statements based on historical costs can present many problems to the users of these statements.

In order to overcome the problems associated with the use of historical cost statements in inflationary periods and to provide greater information to the users of financial data, the Securities and Exchange Commission (SEC) took an unprecedented step in the accounting industry. The SEC, on March 23, 1976, issued Accounting Series Release No. 190 (ASR No. 190), which requires all SEC registrants with inventories and gross property, plant and equipment which aggregate more than $100 million and which comprise more than 10% of the total assets, to disclose certain specified replacement cost data in financial statements filed with the SEC. The required data are: (1) estimated current replacement cost of (a) inventories and (b) productive capacity, at the end of each fiscal year for which a balance sheet is required, and, (2) the approximate amount of (a) cost of sales and (b) depreciation, based on replacement cost for the two most recent full fiscal years. In addition, disclosure will be required for methods of determining replacement costs and any additional information that management believes is necessary to prevent the replacement cost information from being misleading. Disclosure of all data required by ASR No. 190 may be either in a footnote to the financial statements or in a separate section of the financial statements following the notes. In its release the SEC states that the purposes of the required disclosure of current replacement cost information are:

"to provide information to investors and other interested parties which will assist them in obtaining an understanding of the current costs of operating the business. . .[and] to provide information which will enable investors to determine the current cost of inventories and productive capacity as a measure of the current economic investment in these assets. . . "

The SEC's desire to provide users of financial statements with more relevant cost information has the potential to require changes in many other areas. ASR No. 190's asset requirements of $100 million in combined inventories, plant and equipment for disclosing replacement cost data will effect many Air Force contractors. For the past eighteen months, firms such as General Dynamics, Lockheed, McDonnell Douglas, and Northrup have been gathering replacement cost data in an attempt to show what inflationary pressures have done in the areas of inventories and plant capacity. Therefore, it seems advantageous to examine exactly what these firms have been doing in the area of replacement cost accounting and then to analyze how these actions might effect possible government procurement activity.

PART II

THE HOW OF REPLACEMENT COST ACCOUNTING

The intent of the SEC's ASR No. 190 was to have firms show exactly what it would cost them in today's dollars to replace their present inventories and production capacity; thereby, giving a better picture of each firm's financial position. Further, this action was designed to show what the income statements of these firms would look like if these same inventories and production capacities were expressed in today's dollar values and not in terms of what these items cost several years ago. The entire move toward replacement cost accounting was designed to provide a more current analysis of a firm's financial health during inflationary periods. The questions that now must be answered are how are these replacement cost figures derived? How are they presented? And, what effect will they have on a firm's financial statements? Once these questions are answered, then the full impact of replacement cost accounting will be evident.

The SEC defines replacement cost as:

> ". . . the lowest amount that would have to be paid in the normal course of business to obtain a new asset of equivalent operating or productive capability."

For inventories, this presents no particular difficulties since most companies replace inventories continually with similar or identical items. It is a matter then of determining the current cost, at the balance sheet date, of replacing each item of inventory. If the item is purchased in the open market or from a vendor, the current market price or vendor quotation would be the best estimate. When this approach is used, care should be taken, however, to consider possible quantity discounts; and prices should be based on the company's normal purchase quantities. If an item is to be replaced under a long-term supply contract at a price materially below current market prices, the replacement cost would be the contract price. If the contract has only a short time to run, however, the year-end market price should be used. The SEC requires that obsolete or discontinued items be set forth separately, and not be included in replacement cost calculations. These items are not part of continuing operations, and will not be replaced. Also, many companies that employ standard cost systems regularly revalue their inventories at prevailing cost levels. Timing this revaluation to occur at year-end, or doing a supplementary revaluation to determine replacement cost at year-end, would appear to require little additional effort for those firms that have perpetual inventory records.

Thus, the task of computing year-end inventories and restating cost of sales on a replacement cost basis will probably prove to be simpler for most firms than the task of determining the replacement cost of productive capacity. Inventory transactions take place on a regular enough basis for most firms so that they will be able to establish replacement cost with little trouble at year-end. However, determining the replacement cost for new facilities and equipment with <u>equivalent productive capacity</u> presents a real challenge. To accomplish this, it is necessary to determine what replacement facilities and equipment are available and to equate the productivity and cost of operation of the replacement item to the original asset. This poses some difficult problems. The replacement cost of equivalent used" equipment does not satisfy the requirement. In most cases, used equipment would present a temporary rather than a long-range solution to the capacity replacement problem. Where machinery and equipment are involved, a technologically equivalent unit is often not available for all assets. The cost of reconstructing an identical piece of equipment from service parts, to replace a 10-year old machine no longer available commercially, could be substantially above the cost of purchasing a new and more advanced unit. In evaluating the substantial number of replacement models available, each will have different productivity features and different price tags. Even if each individual capital asset is evaluated on an asset-by-asset replacement basis, substantial

latitude is left with the user in selecting the replacement unit to be included.

Since replacement costs for inventories will be easier to estimate than the . . . fixed assets, the SEC has provided some ass . . in developing replacement costs . . . . . . ve capacity. Specifically, in S. . . . . . . Bulletin Release No . . . ., 1976, the Commission provided t. . f. . . ing directions:

> Productive capacity i. a measurement of a company's ab. . . . pro- duce and distribute. . . . roductive capacity of a manufac. . . . . ld be measured by the number . . . its it can presently produce a. . . stribute within a particular time frame; in the case of a telephone company, for example, it would be a measurement of the num. r of telephone calls it can presently complete within a certain time frame.
>
> There is no simple concept of replacement cost which will be applicable in every circumstance. In general, replacement cost of productive capacity means the cost of replacing capacity within the existing business framework of the entity. Thus, replacement cost does not generally contemplate a single time complete replacement of total capacity while totally ignoring the structure of the busi. ss as it exists. Neither does . ean replacement of each of the specific assets currently owned unless that is the way in which the business generally replaces its capacity. Rather, replacement costs should be based on the entity's normal approach to replacement of capacity.

Having determined how these replacement costs are calculated, we will now demonstrate how this data will be presented. As stated earlier, ASR No. 190 requires that replacement costs be presented in either footnotes to the original historical cost statements or in a separate section of these statements. In either case, the data presented will be very similar to that found in Exhibit 1 (careful attention should be made to this exhibit since the data contained in the exhibit will be used in the following two exhibits).

Note: Exhibits 1, 2, and 3 are adapted from the following text: A Primer on Cost Replacement Accounting by William J. Bruns, Jr., and Richard F. Vancil.

EXHIBIT 1

EXAMPLE OF DISCLOSURE OF REPLACEMENT COST AS REQUIRED IN FORM 10-K FILED WITH SECURITIES AND EXCHANGE COMMISSION

C & P COMPANY

Estimated Replacement Cost Information (Unaudited)

The following replacement cost information for certain of the Company's assets has been estimated by management.

December 31, 1977	Historical Cost	Estimated Replacement Cost
	($ millions)	
Inventories	$ 92	$ 97
Productive Capacity	187	272
Less: Accumulated Depreciation	63	86
Net Cost of Capacity	$124	$186
Year Ended December 31, 1977		
Cost of sales	$297	$316
Depreciation	21	26

An examination of the data reveals that replacement cost data clearly reflect that C & P Company's inventories and productive capacity are undervalued in terms of today's costs. Consequently, the firm's cost of sales and depreciation are also understated, thereby resulting in a greater net income basis than would exist if the inventories were expressed, and the equipment depreciated using today's costs. Such information presented in footnote form is a step in the right direction, but in order to really appreciate its magnitude, it should be analyzed in relation to the firm's balance sheet and income statement. Exhibit 2 presents C & P's balance sheet and income statement on a historical cost basis. Exhibit 3 shows the same data with the inventory and productive capacity restated based on the estimated replacement costs shown in Exhibit 1.

By analyzing Exhibits 2 and 3 simultaneously, the real impact of replacement cost accounting can be discerned. Notice total assets in Exhibit 3 are $67 million larger due to increases of $5 million in inventories and $62 million in net productive capacity. Thus, if the firm would have to replace these two critical items today, it would have to pay an additional $67 million because of inflation.

EXHIBIT 2

C & P COMPANY

Balance Sheet
(Based on Historical Costs)

December 31, 1976
($ millions)

ASSETS			
Current Assets:			
Cash		$ 17	
Accounts Receivable		54	
Inventories		92	
			$163
Fixed Assets:			
Land		$ 23	
Productive Capacity	$187		
Less: Accumulated Depreciation	63	124	
			147
Other Assets:			13
Total Assets			$323
EQUITIES			
Current Liabilities:			
Notes Payable		$ 20	
Accounts Payable		41	
Taxes Payable		19	$ 80
Long Term Debt:			56
Owners Equity:			
Common Stock		$122	
Retained Earnings			
January 1, 1976	$ 48		
Add: Net Income	17		
December 31, 1976		65	
			187
Total Equities			$323

Income for the Year 1977
(Based on Historical Costs)
($ millions)

Sales		$371
Costs of Goods Sold		297
Gross Margin		74
Depreciation	$ 21	
Other Expenses	36	
Total Expenses		57
Net Income		$ 17

No dividends were paid to share holders.

EXHIBIT 3

C & P COMPANY

Balance Sheet
(Based on Estimated Replacement Cost for Inventory and Productive Capacity)
($ millions)

ASSETS			
Current Assets:			
Cash		$ 17	
Accounts Receivable		54	
Inventories		97	
			$168
Fixed Assets:			
Land		$ 23	
Productive Capacity	$272		
Less: Accumulated Depreciation	86		
		186	
			209
Other Assets:			13
Total Assets			$390
EQUITIES			
Current Liabilities:			
Notes Payable		$ 20	
Accounts Payable		41	
Taxes Payable		19	
			$ 80
Long Term Debt:			56
Owners Equity:			
Common Stock		$122	
Retained Earnings:			
January 1, 1976	$ 48		
Less: Operating Loss	7		
		41	
Holding Gains		91	
			$254
Total Equities			$390

Income for the Year 1977
($ million)

	Under Historical Cost Accounting	Under Replacement Cost Accounting	Changes due to Accounting Method
Sales	$371	$371	
Cost of Goods Sold	297	316	(19)
Gross Margin	$ 74	$ 55	
Depreciation	$21	$26	(5)
Other Expenses	36	36	
Total Expenses	57	62	
Net Income (Loss)	$ 17	$ (7)	$(24)

The critical point that must be analyzed though is in the income statement. Notice in Exhibit 3, under the replacement cost approach, that the C & P Company shows a net loss of $7 million compared to a reported gain of $17 million using the historical costing data at Exhibit 2.

The critical point that this analysis portrays is that C & P's revenue have been rising due to inflationary pressures, but its dated costs in the areas of depreciation and inventory expense are $24 million off the pace in terms of today's prices. Thus, what is actually being reported using historical costing is artificial profits. The firm has not generated $17 million in real profits as the historical costing method might lead one to believe. It must actually use these $17 million in reported profits as well as an additional $7 million of retained earnings to replace the inventories and productive capacity in terms of today's costs.

Thus, replacement cost accounting demonstrates the true effect that inflation has upon a firm and eliminates the mismatching of current revenues without outdated costs. Having examined the why and how of replacement cost accounting, it is an appropriate time to analyze this latest accounting development in terms of its possible effects in the area of government procurement.

PART III

THE EFFECTS OF REPLACEMENT COST ACCOUNTING

The SEC's pronouncement requiring replacement cost accounting information is mandatory for all firms whose stock is traded publicly and who possesses at least $100 million in inventory and gross property that represent 10% or more of total assets. One industry that is greatly affected by this new accounting convention is the aerospace industry--a prime supplier of major weapon systems for the Air Force. Exhibit 4 shows four representative firms from this industry. All four meet ASR No. 190's asset guidelines. Therefore, each firm must develop and present replacement cost accounting information in conjunction with the annual financial statements presented on a historical cost basis.

With such major firms as General Dynamics, Lockheed, McDonnell Douglas and Northrup having to revalue their inventories and productive capacities to meet SEC requirements, many questions are developing as to how this data will effect future company decisions. With these firms realizing that they must replace inventories and depreciable assets at today's inflated prices, such knowledge may impact considerably upon future pricing decisions and contract negotiations. Assuming that the fictious C & P Company portrayed in Exhibits 1, 2, and 3 is representative of such firms as those found in the aerospace industry and those that are major government suppliers, we can begin to analyze what possible effect this replacement cost data will have in the government procurement arena.

EXHIBIT 4

AEROSPACE FIRMS MEETING SEC ASSET REQUIREMENTS FOR REPLACEMENT COST ACCOUNTING DISCLOSURE
(dollar figures in millions)*

Year Ended	(1) Gross Property	(2) Inventories	(3) (1)+(2) Total	(4) Total Assets	(3)÷(4) % of Total Assets
31 Dec	General Dynamics				
1976	1,153	571	1,724	2,006	86%
1975	1,022	521	1,543	1,863	83%
1974	922	470	1,392	1,634	85%
31 Dec	Lockheed				
1976	742	405	1,147	1,521	75%
1975	733	388	1,121	1,389	81%
1974	709	893	1,602	1,899	84%
31 Dec	McDonnell Douglas				
1976	684	1,494	2,178	2,391	91%
1975	666	1,638	2,304	2,466	93%
1974	672	1,659	2,331	2,459	95%
31 Dec	Northrup				
1976	250	121	371	597	62%
1975	232	142	374	544	69%
1974	217	129	346	496	70%

*Data extracted from Standard & Poor Corporation Industrial Report.

If we assume that C & P Company is a major supplier of Air Force resources and operates on a cost plus a fixed fee basis, then much may be done by C & P to increase the costs that should be reported to the contracting officer. The historical cost data in Exhibit 2 shows that C & P would bill the Air Force $297 million in cost of goods sold and $57 million in operating expenses and generate a reported net income of $17 million after considering the fixed fees charged. However, by complying with SEC replacement cost requirements, the firm now realizes that in order to replace the inventory sold to the Air Force, it must now repurchase

it at today's prices of $316 million, indicating a $19 million increase in costs actually reported. Further, if the firm was to provide adequate depreciation allowances for the replacement of its productive capacity, then an additional $5 million would have to be set aside as depreciation expense (See Exhibit 3).

Thus, through replacement cost accounting, C & P now realizes that by agreeing to a cost plus a fixed fee basis it is "behind the power curve" in terms of replacing its assets at today's costs. If it had just continued to report operations on a historical cost basis, it would not have realized that the $17 million in "operating" profits as well as an additional $7 million would have to be used just to replace the assets expended in its latest year of operation. From an economic standpoint then, the firm has not generated a profit of $17 million, but rather has suffered a $7 million loss in terms of today's inflated prices.

Armed with these facts and aware of the impact that inflation has upon the operations of the firm, C & P may attempt to increase its reported costs to the government. Herein lies the crux of the problem with replacement cost accounting information within the government procurement environment. Most procurement contracts are worded so that the supplier is reimbursed for his actual or "out of pocket" costs. These are the costs reported on the firm's historical financial statements and the costs that should be reported in a cost plus fixed fee government contract. However, the supplier will now realize that he is not adequately providing for the replacement of the assets consumed by the Air Force in terms of today's higher costs. By being aware of this replacement data, the firm may attempt to make up for the ground that it is losing by reporting costs that are greatly increased over the historical cost incurred. It will then be up to the procurement authorities to insure that the costs that are reported are, in fact, the historical or actual costs agreed upon.

Obviously, a supplier may not revert to such covert actions as reporting fictious higher costs, so as to stay even with rising prices and report an economic profit, but it may start to look for a new negotiated contract basis. Instead of seeking renumeration on a cost plus a fixed fee basis, since the supplier is now aware that its cost basis is becoming outdated in an inflationary period, it may seek a negotiated full price contract. The price probably would be set substantially higher than what was charged in prior years under the cost plus system since the supplier will be attempting to cover not only historical costs and realize a profit, but it will also be attempting to provide for inflationary cost increases. In this way, the supplier will be staying even with inflation and will thus have a hedge against the economic losses reported under replacement cost accounting. No longer will the firm's cost basis be outdated and its fixed fee eaten away by inflationary price increases.

Thus, the SEC's latest pronouncement in the accounting industry at first glance seemed a long way off from the world of government contracts and procurement actions. However, once the full impact of this recent accounting change is felt and corporate executives see in print what they may have only suspected, we predict that many major government contractors will be pushing for some type of rate structure which will compensate them for this phenomenon that occurs in periods of rising prices. If the future does hold such events, then procurement specialists should be prepared for this and should realize the many complexities associated with this newest type of financial reporting. If replacement cost figures begin to directly enter into contract negotiations, then the Air Force contracting representatives must understand why these figures are created, how they are arrived at, and how they effect procurement activities. What is now appearing in footnotes to historical financial statements, indicating the replacement value of inventories and productive capacity, may soon become the center of attention for many government activities.

CONTRACTOR FINANCIAL DATA RETRIEVAL AND ANALYSIS SYSTEM

David M. Koonce
Chairman, DoD Contract Finance Committee

I. INTRODUCTION

The increasing number of management decisions facing Department of Defense (DoD) acquisition executives require a comprehensive analysis of the financial impact of policy changes on major defense contracts. For example, on programs with large cost overruns or claims, DoD management wants answers to such questions as "How much money can the company borrow?" or "Will the company go broke unless we increase the contract price?"

There is a need for an in-depth financial analysis on major acquisition programs. We should be doing everything we can to predict financial problems with major defense contractors in order to avoid drastic measures of financial relief such as unusual progress payments or extraordinary contractual actions pursuant to Public Law 85-804. Under current practice many post-award financial reviews are made by CPA firms under contract to the DoD. This practice is expensive, time-consuming, and does not lend itself to the "what if" projections that are an essential part of the decision-making process.

The purpose of this paper is to describe the new Contractor Financial Data Retrieval and Analysis System (FINANDAS), which is a computerized system designed to assist the DoD in the financial analysis of major defense contractors. The system was developed by the Logistics Management Institute (LMI) under the sponsorship of the Director of Contracts and Systems Acquisition within the Office of the Under Secretary of Defense for Research and Engineering (Acquisition Policy).[1] As Chairman of the DoD Contract Finance Committee, I am responsible for the implementation of the system. This paper will discuss the features of FINANDAS, how the system can be used to solve acquisition problems, and system implementation status.

II. DESCRIPTION OF FINANDAS

FINANDAS is a computerized system for obtaining and analyzing financial statements of major defense contractors. Users, through a time-sharing computer terminal, can retrieve stored data and obtain financial analyses. Reports are printed on a time-sharing terminal connected by a telephone link with the General Electric "Copper Impact" computer network. Financial statements of companies not in the system can be fed into the computer for analysis and the system can make projections and simulations. A typical analysis costs about $15 per company.

While the system can handle data for 2700 companies, it presently includes financial information about 900 publicly-owned companies. To illustrate the system's utility, there were 87 publicly-held companies on the 1977 list of contractors receiving the largest volume of DoD prime contract awards; 74 of these are included in the 900-company data bank.

Most stored financial data is obtained from Standard & Poor's Compustat Services, Inc., a subsidiary of Standard & Poor's Corporation. This information, called "Compustat," includes 133 elements of audited annual financial data. Five years of financial statements, including historical trends, are available through FINANDAS. Several ratio reports also are available. Furthermore, with the user furnishing the assumptions, the system can produce five-year projections.

ANALYTICAL OBJECTIVES

FINANDAS is designed to analyze liquidity through such ratios as current assets/current liabilities (current ratio) and cash plus marketable securities/accounts payable (quick ratio).

In the long run, a corporation's fortunes will often rest upon the strength of its capital structure. Solvency is the relationship of debt to equity and assets. Therefore, FINANDAS is designed to look at such factors as capital structure, the issuance of additional debt or equity, and the cost of capital. Ratios analyzed include debt/equity, tangible net assets/long-term debt, and net working capital/short-term debt.

Profitability probably receives the widest visibility of any component of financial analysis. Net income/sales, and net income/assets are the traditional measures of profitability among financial analysts. In recent years, cash flow, or "actual cash" generated from operations, has become recognized as an equally important aspect of profit analysis. Cash flow is particularly important where non-cash charges depress reported profits. Because fixed charges must be covered by real cash, cash flow has become a key indicator of near term visibility. Furthermore, cash flow over the term of a contract will be a vital determinant in any change of the DoD contract financing provision.

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1 "Contractor Financial Data Retrieval and Analysis System" (FINANDAS), Logistics Management Institute, Task 75-11, January 1977. Much of the description of the system has come from this report.

ANALYTICAL REPORTS

The Balance Sheet, often called the "Statement of Financial Position," identifies the year-end amounts of a company's assets and liabilities. Most of the accounts shown on the Balance Sheet are significant, and their trends should be reviewed. Trends for several key accounts are flagged with a "P" or an "N." for important Positive or Negative indicators of financial health. A unique feature of the projected balance sheet is the entry for "additional borrowing," which indicates the cumulative excess of cash requirements over cash generated. A projected balance sheet is shown on Table 1.

The Income and Retained Earnings Statement is another traditional analytical report. Key data for trend review in the income section are: Net Sales, Gross Income, Operating Income, Income Before Tax, Income Before Extras (extraordinary items) and Net Income. A projected income statement is shown on Table 2.

The accounting name for the Changes in Working Capital report is the Statement of Changes in Financial Position, but it is often referred to as the "Sources and Applications of Funds," or "Funds Flow" statement. The Changes in Working Capital report is oriented more toward the total net working capital rather than to cash. Such an orientation reflects the need for working capital to fund sales (through accounts receivable), provide sufficient work-in-process inventory for production, and maintain a finished goods inventory to meet sales commitments. In government contracting, working capital is required to complete the product before payment at delivery or at certain milestones. This report is shown on Table 3.

The Annual Ratios report contains key ratios to evaluate performance, capitalization, liquidity and debt coverage. The performance ratios measure the return (income) on equity, sales, capital and assets. The capitalization ratios measure the balance between use of debt for leverage and the need for sufficient equity to insure financial soundness. Because the liquidity of a company is a direct measure of its financial health, a large number of liquidity ratios are provided. In addition to the current ratio and the acid test, the liquidity ratios analyze receivables, inventory, payables, working capital and cash flow. The debt coverage ratios indicate the cash cushion available to pay interest on debt, or meet commitments for debt repayment and capital expenditures. As an overall measure of financial health, the system provides the Z-Score, a weighted sum of selected ratios. A projected report is shown on Table 4.

The Forecasting Factor report, shown on Table 5, aids in projecting a company's financial position. This report contains factors useful in specifying assumptions for projections.

The Projection Assumptions report, shown on Table 6, is included in the computer output to make explicit the assumptions used. All assumptions appear by account projected, and are identified by source: "input" (provided by the user) or "default" (provided automatically when no user assumption is input).

III. APPLICATION OF FINANDAS

FINANDAS has been used on several occasions to analyze the cash flows and projected cash needs for major DoD contractors with financing problems. The first task was to gather history using the Compustat data base and analyze the current financial status of the company. The next step was to develop projection assumptions using the trends and ratios from FINANDAS. It was a simple job to input these assumptions and obtain the projected financial statements. These reports were reviewed with DoD acquisition management and additional projections were quickly made based on alternative assumptions. Some of the assumptions we investigated included:

- the impact of various levels of government financing
- program cost overruns
- settlement of claims
- tax write-offs

The key items we addressed were cash flow and the amount of additional borrowing required. The projections not only indicated how much additional borrowing was needed, but provided an annual repayment schedule. This is critical to lenders since the time of repayment is an important consideration in loan availability. The immediate access to audited financial data and the rapid turn-around of projections has made FINANDAS an effective tool for our analysis of contractor financing needs.

IV. IMPLEMENTATION STATUS

The development of FINANDAS by LMI is complete and a user's manual has been published. We are currently organizing a training program to be conducted by the Services for the use of personnel involved with the acquisition of major weapon systems. The "Compustat" data base and the FINANDAS computer programs are available to subscribers of the Air Force "Copper Impact" computer network.

TABLE 1
USER PROJECTED
BALANCE SHEET OF LOCKHEED CORP

INDUSTRY: AIRCRAFT & PARTS DATA PRINTED IN MILLIONS

MONTH FISCAL YR ENDS FISCAL YEAR	DEC 1977	DEC 1978	DEC 1979	DEC 1980	DEC 1981	TRENDS
ASSETS						
CASH & EQUIVALENTS	142.9	151.1	173.7	165.3	172.2	2.3%
ACCOUNTS RECEIVABLE	205.1	215.4	226.1	237.4	242.?	5.0%S
INVENTORIES	425.5	446.6	463.7	471.9	516.4	5.0%S
OTHER CURRENT ASSETS	74.9	78.?	82.?	86.5	91.?	5.0%S
TOTAL CURRENT ASSETS	848.4	931.7	951.1	961.4	1025.8	4.5%
GROSS PLANT	756.1	770.7	785.5	800.6	815.1	1.9%S
ACCUM. DEPRECIATION	515.5	536.8	558.6	580.8	603.4	4.0%S
NET PLANT	240.6	233.9	226.9	219.9	212.7	-3.0%T
INVESTMENTS	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0%
INTANGIBLES	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0%
OTHER ASSETS	499.8	499.8	499.8	499.8	499.8	0. %S
TOTAL ASSETS	1588.9	1665.3	1677.8	1701.0	1741.3	2.1%S
LIABILITIES & EQUITY						
ACCOUNTS PAYABLE	227.8	239.1	250.9	263.4	276.5	5.0%S
MATURING NOTES &DEBT	25.1	97.8	97.8	207.8	-0.0	93.5%S
ADDITIONAL BORROWING	0.	0.	0.	0.	115.4	-0.0%
INCOME TAXES PAYABLE	11.5	12.9	14.4	16.2	18.?	11.8%S
OTHER CURRENT LIAB.	563.3	591.3	620.7	651.5	683.9	5.0%S
TOTAL CURRENT LIAB.	827.7	941.1	983.8	1138.?	1094.8	7.9%
LONG TERM DEBT	536.1	438.3	340.5	132.7	132.7	-32.0%S
OTHER L-T LIAB.	4.4	4.4	4.4	4.4	4.4	0. %S
TOTAL LIABILITIES	1368.2	1383.8	1328.7	1276.0	1231.9	-2.9%S
MINORITY INTEREST BS	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0%
PREFERRED STOCK	47.4	47.4	47.4	47.4	47.4	0. %S
COMMON STOCK	11.4	11.4	11.4	11.4	11.4	0. %S
CAPITAL SURPLUS	88.1	88.1	88.1	88.1	88.1	0. %S
RETAINED EARNINGS	73.8	134.6	202.2	278.2	362.6	47.6%P
SHAREHOLDERS EQUITY	220.7	281.5	349.1	425.1	509.5	23.2%P
TOTAL LIAB. & EQUITY	1588.9	1665.3	1677.8	1701.0	1741.3	2.1%S
WORKING CAPITAL	20.8	-9.4	-32.7	-157.5	-65.9	-0.0%
LONG TERM CAPITAL	756.8	719.8	689.6	557.8	642.2	-5.7%M
TANGIBLE NET WORTH	220.7	281.5	349.1	425.1	509.5	23.2%P

DATA SOURCE: SEE PRIOR ANALYZET OUTPUT FOR THIS COMPANY

CONTRACTOR FINANCIAL DATA RETRIEVAL & ANALYSIS SYSTEM 11 APR 78 P13

TABLE 2

USER PROJECTED

INCOME & RETAINED EARNING STATEMENT OF GRUMMAN CORP

INDUSTRY: GUIDED MISSILES & SPACE VEHC DATA PRINTED IN: MILLIONS

MONTH FISCAL YR ENDS FISCAL YEAR	DEC 1977	DEC 1978	DEC 1979	DEC 1980	DEC 1981	TRENDS
INCOME						
NET SALES	1577.2	1656.0	1738.8	1825.8	1917.0	5.0%
COST OF SALES	1380.9	1449.9	1522.4	1598.6	1678.5	5.0%S
GROSS INCOME	196.3	206.1	216.4	227.2	238.6	5.0%S
SELLING, GEN & ADMIN	137.9	144.9	152.0	159.6	167.6	5.0%S
DEPRECIATION IS	18.0	18.9	19.9	20.9	21.9	5.0%S
OPERATING INCOME	40.4	42.4	44.5	46.7	49.1	5.0%S
INTEREST EXPENSE	18.7	18.8	18.2	17.5	16.7	-2.9%S
SPECIAL ITEMS	0.	0.	0.	0.	0.	-0.0%
OTHER INCOME/-EXP	21.5	22.5	23.7	24.8	26.1	5.0%S
INCOME BEFORE TAX	43.2	46.2	50.0	54.1	58.5	8.0%S
INCOME TAXES	17.8	19.1	20.6	22.3	24.2	8.0%S
MINORITY INTEREST IS	0.6	0.6	0.7	0.7	0.8	8.0%S
INCOME BEFORE EXTRAS	24.7	26.5	28.6	31.0	33.5	8.0%S
EXTRAORDINARY ITEMS	0.	0.	0.	0.	0.	-0.0%
NET INCOME/-LOSS	24.7	26.5	28.6	31.0	33.5	8.0%S
RETAINED EARNINGS						
BEGINNING BALANCE	121.2	141.1	162.6	186.3	212.4	15.0%P
RESTATEMENT	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0%
AS RESTATED	121.2	141.1	162.6	186.3	212.4	15.0%P
PLUS NET INC/-LOSS	24.7	26.5	28.6	31.0	33.5	8.0%S
LESS DIVIDENDS	4.9	4.9	4.9	4.9	4.9	0. %S
OTHER CHANGES	0.	0.	0.	0.	0.	-0.0%
ENDING BALANCE	141.1	162.6	186.3	212.4	241.0	14.3%P
INCREASE/-DECREASE	19.8	21.5	23.7	26.1	28.6	9.7%S

DATA SOURCE: SEE PRIOR ANALYZET OUTPUT FOR THIS COMPANY

CONTRACTOR FINANCIAL DATA RETRIEVAL & ANALYSIS SYSTEM 11 APR 79 P14

TABLE 3
USER PROJECTED
CHANGES IN WORKING CAPITAL OF ROHR INDUSTRIES

INDUSTRY: AIRCRAFT PARTS & AUX EQUIP DATA PRINTED IN: THOUSANDS

MONTH FISCAL YR ENDS FISCAL YEAR	JUL 1978	JUL 1979	JUL 1980	JUL 1981	JUL 1982	TRENDS
SOURCES						
INCOME BEFORE EXTRAS	3743.	4490.	5731.	7291.	9268.	25.9%P
TOTAL DEPRECIATION	7687.	8024.	8376.	8744.	9128.	4.4%S
OTHER OPNS SOURCES	-932.	-1119.	-1427.	-1617.	-2307.	-0.0%
TOTAL FROM OPNS	10498.	11401.	12680.	14224.	16088.	11.3%P
SALE OF PLANT, ETC.	1668.	1742.	1818.	1898.	1981.	4.4%S
SALE OF STOCK	0.	0.	0.	0.	0.	-0.0%
NEW LONG TERM DEBT	0.	0.	0.	0.	0.	-0.0%
OTHER SOURCES	0.	0.	0.	0.	0.	-0.0%
TOTAL SOURCES	12167.	13142.	14498.	16122.	18069.	10.5%P
APPLICATIONS						
DIVIDENDS	-0.	-0.	-0.	-0.	-0.	-0.0%
CAPITAL EXPENDITURES	9596.	10017.	10457.	10916.	11395.	4.4%S
INVESTMENTS&ACQ	0.	0.	0.	0.	0.	-0.0%
DEBT MATURITIES	13925.	25029.	30029.	45029.	-0.	44.8%S
TREASURY STOCK PURCH	0.	0.	0.	0.	0.	-0.0%
OTHER APPLICATIONS	-500.	-668.	-956.	-1325.	-1794.	-0.0%
TOTAL APPLICATIONS	23021.	34378.	39530.	54620.	9600.	-12.1%
NET INCREASE/-DECR	-10855.	-21236.	-25032.	-38498.	8468.	-0.0%
SUMMARY OF CHANGES						
CASH & EQUIVALENTS	55205.	-4162.	-7104.	-5900.	-13182.	-0.0%
ACCOUNTS RECEIVABLE	152.	4264.	4477.	4701.	4936.	102.4%
INVENTORIES	3803.	4008.	4208.	4418.	4638.	5.1%S
OTHER CURRENT ASSETS	-492.	230.	241.	253.	266.	-0.0%
CUR ASSET INCR/-DECR	58669.	4340.	1822.	3472.	-3342.	-0.0%
ACCOUNTS PAYABLE	925.	1921.	2016.	2117.	2222.	20.3%
MATURING NOTES&DEBT	13023.	11104.	5000.	15000.	-45029.	-0.0%
ADDITIONAL BORROWING	-0.	-0.	-0.	-0.	-0.	-0.0%
INCOME TAXES PAYABLE	54318.	11269.	18491.	23440.	29513.	-4.8%
OTHER CURRENT LIAB.	1187.	1282.	1346.	1413.	1483.	5.6%
CUR LIAB. INCR/-DECR	69524.	25576.	26853.	41970.	-11810.	-0.0%
DUE TO RESTATEMENT	-0.	-0.	-0.	0.	-0.	-0.0%
NET INCREASE/-DECR	-10855.	-21236.	-25032	-38498.	8468.	-0.0%
CASH FLOW	10210.	11113.	12393.	13936.	15800.	11.6%P

DATA SOURCE: SEE PRIOR ANALYZET OUTPUT FOR THIS COMPANY

CONTRACTOR FINANCIAL DATA RETRIEVAL & ANALYSIS SYSTEM 11 APR 78 P15

TABLE 4
USER PROJECTED
ANNUAL RATIOS FOR ANALYSIS OF BOEING CO

INDUSTRY: AIRCRAFT DATA PRINTED IN PERCENTS*

MONTH FISCAL YR ENDS / FISCAL YEAR		DEC 1977	DEC 1978	DEC 1979	DEC 1980	DEC 1981	TRENDS
PERFORMANCE							
INCOME/AVG EQUITY		10.3	10.2	10.1	9.9	9.8	-0.1 S
INCOME/SALES		2.8	2.9	3.0	3.0	3.1	0.1 S
INC BIT/AVG CAPITAL		14.2	14.1	14.0	13.9	13.7	-0.1 S
INC BIT/ASSETS	Z	8.7	8.7	8.7	8.7	8.7	0.0
NET EARN/ASSETS	Z	36.8	39.5	42.2	44.7	47.1	2.6 P
SALES/ASSETS	Z	203.1	201.0	198.5	195.8	193.0	-2.5 N
SALES/AVG EQUITY		363.3	350.6	338.2	326.2	314.8	-12.2 N
SALES/WORKING CAP.		556.6	506.2	464.1	428.4	393.7	-40.4 N
SALES/NET PLANT		1049.9	1172.3	1315.7	1485.4	1689.0	159.1 P
APPROX. P/E RATIO	R	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
CAPITALIZATION							
L-T DEBT/EQUITY		9.8	7.0	5.5	4.1	3.8	-1.3 P
LIAB./EQUITY		71.7	67.3	63.4	59.8	56.5	-3.8 P
L-T DEBT/L-T CAPITAL		8.1	6.5	5.2	4.0	3.7	-1.1 P
BK EQUITY/TOT DEBT	AZ	1002.9	1242.2	1555.4	1994.3	2636.5	401.9 P
LIQUIDITY							
CURRENT RATIO		210.2	221.3	232.3	243.3	258.5	11.9 P
ACID TEST		135.9	146.9	158.0	169.0	183.1	11.7 P
DAYS RECEIVABLES	R	25.3	25.3	25.3	25.3	25.3	0.0
RECEIVABLES/WORK CAP		38.6	35.1	32.2	29.7	27.3	-2.8 N
INVENTORY TURNS	R	8.1	8.1	8.1	8.1	8.1	-0.0 S
INVENTORIES/WORK CAP		61.8	56.1	51.4	47.5	43.6	-4.5 P
DAYS PAYABLES	R	38.2	38.2	38.2	38.2	38.2	-0.0 S
WORKING CAP/ASSETS	Z	36.5	39.7	42.8	45.7	49.0	3.1 P
L-T DEBT/WORKING CAP		14.0	10.5	7.8	5.6	4.2	-2.3 P
CSH FLO/TOT LIAB		23.7	24.4	25.0	25.6	26.2	0.6 S
COVERAGE							
INC BIT/INTEREST		1639.3	2027.1	2468.5	3054.9	3881.4	551.2 P
CSH FLO/DBT MAT+C.E.		239.6	251.2	260.4	270.2	331.3	20.2 P
OVERALL STRENGTH							
Z- SCORE TOTAL	Z	9.29	10.78	12.71	15.38	19.28	2.5 P

* EXCEPT WHERE MARKED R(RATIO) OR Z-SCORE TOTAL
Z THESE ARE THE COMPONENTS & TOTALS OF THE Z SCORE-SEE MANUAL FOR EXPLANATION
AZ APPROXIMATION TO MARKET EQUITY/TOT DEBT--Z SCORE TOTAL ONLY APPROXIMATE
SEE RELATIVE INCOME STATEMENT AND RELATIVE BALANCE SHEET FOR OTHER KEY RATIOS
DATA SOURCE: SEE PRIOR ANALYZET OUTPUT FOR THIS COMPANY

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TABLE 5

FORECASTING FACTORS OF FMC CORP

INDUSTRY: CONSTRUCTION MACHINERY & EQP DATA PRINTED IN PERCENTS

MONTH FISCAL YR ENDS / FISCAL YEAR	DEC 1972	DEC 1973	DEC 1974	DEC 1975	DEC 1976	WTD AVERAGE	TREND
FORECASTED VARIABLE / RELATED VARIABLE							
SALES GROWTH							
NET SALES	10.65	14.79	20.64	10.50	-6.43	3.58	-3.84
COST OF SALES							
NET SALES	75.13	75.83	78.14	76.09	73.62	75.03	-0.28
SELLING,GEN & ADMIN							
NET SALES	14.69	14.15	13.40	13.26	14.01	13.79	-0.23
DEPRECIATION IS							
PRIOR GROSS PLANT	5.17	6.29	6.50	5.86	4.58	5.29	-0.16
INTEREST EXPENSE							
AVG. TOTAL DEBT	5.81	6.28	8.05	7.65	7.94	7.64	0.56 S
OTHER INCOME/-EXP.							
NET SALES	0.86	1.18	1.50	0.81	0.95	0.99	-0.02
INCOME TAXES							
INCOME BEFORE TAX	32.61	28.46	19.50	28.49	37.79	32.27	1.04
MINORITY INTEREST IS							
INCOME AFTER TAX	0.77	0.92	1.04	0.71	0.49	0.65	-0.08
CASH							
ACCOUNTS PAYABLE	15.13	6.99	3.75	37.93	93.82	58.24	18.83
ACCOUNTS RECEIVABLE							
NET SALES	17.30	18.14	14.70	13.12	13.81	14.24	-1.20 S
INVENTORIES							
CS + DEPR IS	24.61	24.50	26.90	23.40	23.55	24.06	-0.32
OTHER CURRENT ASSETS							
CS+SGA+CAP EXP	2.22	2.83	3.28	2.56	3.86	3.30	0.30
ACCOUNTS PAYABLE							
CS+SGA+CAP EXP	8.27	9.17	10.60	13.26	16.20	13.83	1.99 S
INCOME TAXES PAYABLE							
INCOME TAXES	38.89	104.44	92.73	110.74	83.94	90.21	9.64
OTHER CURRENT LIAB.							
CS+SGA+CAP EXP	6.73	6.07	5.77	6.98	7.70	7.12	0.29
PLT SOLD&RETIRED							
PRIOR GROSS PLANT	5.57	2.66	4.54	2.34	1.90	2.62	-0.76
ACC DEPR. SOLD&RET.							
PLT SOLD&RETIRED	68.64	75.02	85.45	74.00	72.36	74.34	0.64
DIVIDENDS							
COM + PREF STOCK	18.12	18.66	19.60	19.97	21.08	20.28	0.73 S
CAPITAL EXPENDITURES							
PRIOR GROSS PLANT	13.06	12.26	18.87	14.86	8.45	11.88	-0.66

WEIGHTED AVERAGE-EXPONENTIAL WEIGHTS,CURRENT YEAR AT .5

DATA SOURCE: INVESTORS MANAGEMENT SCIENCES ,INC. FILE DATED FINAL

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TABLE 6

PROJECTION ASSUMPTIONS FOR INTL BUSINESS MACHINES CORP

INDUSTRY: OFFICE COMPUTING & ACCTG MCH

PROJECTED VARIABLE	TYPE	PROJECTION METHOD
NET SALES	DEFAULT	GROWS AT 5.00% FROM LATEST YEAR
COST OF SALES	DEFAULT	23.71% OF NET SALES (PRIOR YEAR)
SELLING, GEN.&ADMIN.	DEFAULT	39.58% OF NET SALES (PRIOR YEAR)
DEPRECIATION IS	DEFAULT	12.45% OF PRIOR GROSS PLANT (PRIOR YEAR)
INTEREST EXPENSE	DEFAULT	9.85% OF AVG. TOTAL DEBT (PRIOR YEAR)
SPECIAL ITEMS	DEFAULT	SET TO ZERO
OTHER INCOME/-EXP.	DEFAULT	2.79% OF NET SALES (WTD.AVG.)
INCOME TAXES	DEFAULT	46.56% OF INCOME BEFORE TAX (WTD.AVG.)
MINORITY INTEREST IS	DEFAULT	* NOT PROJECTED-HISTORY ZERO OR NOT AVAIL.
EXTRAORDINARY ITEMS	DEFAULT	SET TO ZERO
DIVIDENDS	DEFAULT	37.42% OF COM. + PREF. STOCK (WTD.AVG.)
OTH.RET.EARNS.CHGS.	DEFAULT	SET TO ZERO
MINIMUM CASH BALANCE	DEFAULT	990.64% OF ACCOUNTS PAYABLE (WTD.AVG.)
ACCOUNTS RECEIVABLE	DEFAULT	16.65% OF NET SALES (WTD.AVG.)
INVENTORIES	DEFAULT	15.78% OF COST SALES + DEPR. (PRIOR YEAR)
OTHER CURRENT ASSETS	DEFAULT	3.31% OF CS + SGA + CAP. EXP.(WTD.AVG.)
INVESTMENTS	DEFAULT	ROLLED FORWARD, ADDING INVESTMENTS & ACQ.
INTANGIBLES	DEFAULT	* NOT PROJECTED-HISTORY ZERO OR NOT AVAIL.
OTHER ASSETS	DEFAULT	SAME AS PRIOR YEAR OTHER ASSETS
ACCOUNTS PAYABLE	DEFAULT	11.78% OF CS + SGA + CAP. EXP.(WTD.AVG.)
MATURING NOTES&DEBT	DEFAULT	TAKEN FROM HISTORICAL DATA
INCOME TAXES PAYABLE	DEFAULT	63.39% OF INCOME TAXES (WTD.AVG.)
OTHER CURRENT LIAB.	DEFAULT	2.85% OF CS + SGA + CAP. EXP.(PRIOR YEAR)
OTHER L-T LIAB.	DEFAULT	SAME AS PRIOR YEAR OTHER L-T LIAB.
MINORITY INTEREST BS	DEFAULT	* NOT PROJECTED-HISTORY ZERO OR NOT AVAIL.
PREFERRED STOCK	DEFAULT	* NOT PROJECTED-HISTORY ZERO OR NOT AVAIL.
COMMON STOCK	DEFAULT	SAME AS PRIOR YEAR COMMON STOCK
CAPITAL SURPLUS	DEFAULT	SAME AS PRIOR YEAR CAPITAL SURPLUS
TOTAL DEPRECIATION	DEFAULT	11.25% OF PRIOR GROSS PLANT (PRIOR YEAR)
OTHER OPNS. SOURCES	DEFAULT	23.50% OF NET INCOME (WTD.AVG.)
PLT. SOLD & RETIRED	DEFAULT	* NOT PROJECTED-HISTORY ZERO OR NOT AVAIL.
ACC.DEPR.-SOLD&RET.	DEFAULT	* NOT PROJECTED-HISTORY ZERO OR NOT AVAIL.
SALE OF PLANT, ETC.	DEFAULT	* NOT PROJECTED-HISTORY ZERO OR NOT AVAIL.
SALE OF STOCK	DEFAULT	SET TO ZERO
NEW LONG-TERM DEBT	DEFAULT	SET TO ZERO
OTHER SOURCES	DEFAULT	SET TO ZERO
CAPITAL EXPENDITURES	DEFAULT	19.65% OF PRIOR GROSS PLANT (WTD.AVG.)
INVESTMENTS & ACQ.	DEFAULT	SET TO ZERO
DEBT MATURITIES	DEFAULT	TAKEN FROM HISTORICAL DATA
TREASURY STOCK PURCH	DEFAULT	SET TO ZERO
OTHER APPLICATIONS	DEFAULT	CALC - BALANCE CHANGE IN L/T ACCOUNTS
PREFERRED DIVIDENDS	DEFAULT	* NOT PROJECTED-HISTORY ZERO OR NOT AVAIL.

NOTE: WHERE TYPE IS 'DEFAULT', USER GAVE NO ASSUMPTION
THEREBY ACCEPTING THE DEFAULT METHOD

ORGANIZATION, DESIGN, AND MEASUREMENT

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CENTRALIZED VERSUS DECENTRALIZED ITEM MANAGEMENT WITHIN HQ, ARRCOM

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INTRODUCTION

The purpose of this paper is to present a synopsis of a study on centralized versus decentralized management and item management conducted within Headquarters, ARRCOM from July 1977 through April 1978. The final study report exceeded 400 pages, inclusive of rather extensive documentation and reference material in the Appendices. The full report will be available through the Defense Logistics Studies Information Exchange for those who may wish to pursue the detail and back-up material. This synopsis will provide highlights and extracts for those whose principal interest is in the general concept of centralized versus decentralized management, study methodology employed, lessons learned, and possible application to a similar situation within their own organizations.

SUMMARY/ABSTRACT

The study findings indicate that neither extreme;i.e., total centralization or total decentralization, is practical or desirable. The preferred and most often utilized organizational structure appears to be a combination of both concepts. In that respect, the current inventory management alignment within HQ, ARRCOM is a combination of centralization and decentralization, and its continuation was highly rated in the study analysis and conclusions. A high potential alternative for the longer term involves a partial centralization; i.e., an increase in centralization over that of the current alignment by consolidating the inventory management of quality assurance equipment (FATE) and depot ammunition maintenance equipment (APE) into the existing NICP organizational elements, while leaving industrial production material outside of the NICP management unless the items are sold or issued.

The study also found that not only is there no clear cut "best" answer in the question of centralization versus decentralization, there is a definite lack of agreement as to the definition, application, advantages, and disadvantages of either option. This general lack of agreement, or disparity, in definition and use of terms was also found to apply to subject related terms such as: Item Manager, Inventory Manager, and Inventory Management. This lack of common terminology was found not only in colloquial usage, but surfaced in the research of regulations and academic texts.

The study also found that the location (centralized or decentralized) of personnel performing inventory management was not as significant as the establishment of, training in, and adherence to standardized procedures, both off-line and CCSS automated.

STUDY SYNOPSIS/EXTRACTS

Subject Matter: The study researched and analyzed the alternatives of centralization and decentralization of organizations for item/inventory management within HQ, ARRCOM. Emphasis was on the qualitative aspects of the organizational alignment of Item/Inventory Managers for the performance of supply (NICP) functions.

Background: A prior study on unbilled shipments of material identified the existing decentralized alignment of item managers as a possible detrimental factor in billing/system deficiencies. Current study was directed by CG, ARRCOM to be performed as an in-house Task Force effort. Study began July 1977 with study completion in April 1978.

Purpose/Objectives: The study was to identify the alternatives of centralized and decentralized Item/Materiel management within HQ, ARRCOM to perform an objective analysis of the alternatives, and make recommendations as to the preferred alternative, functional alignments, and other actions as determined by the study findings. The study analysed and compared four alternatives for organizational alignment of inventory management. The alternatives analysed are: Continuation of Current Alignment: Further Decentralization; Partial Centralization; and Total Centralization. Continuation of current alignment was considered to be the basic situation against which the other three alternatives were compared. The current alignment, referred to as "Status Quo" in the study text, was defined as being subsequent to October 1977, and assumed implementation of several "in-process" changes; i.e., fully operational establishment of DRSAR-DA as the NICP for Conventional Ammunition under the SM concept; the A2C system for assigning MCN's and loading DRSAR-PD industrial components into the NSNMDR; full implementation of the Customer Order Control Point (COCP) in DRSAR-CP; and full implementation of all approved recommendations of the prior study on

"Delivered-Unbilled System Deficiencies."

METHODOLOGY

The study was conducted by a Task Force composed of three groups: A Study Advisory Group (SAG) to provide advice and guidance; a Primary Working Group (PWG) which was the principal conductor of the study; and a Technical Support Group (TSG) to provide technical input and information on functional performance of item/materiel management. The study was conducted in compliance with the requirements of AR 5-5 and DARCOMR 10-1 as applicable. The following methodology was employed in the performance of the study:

a. Conduct literature research. This included such sources as prior internal staff studies, TASS, DLSIE, DDC, AMETA, other Readiness Commands, private industry, educational institutions and libraries. (Reference Bibliography, and Appendices B and H of the full study reports.)

b. Conduct internal (HQ, ARRCOM) survey through a questionnaire.

c. Compile and analyze survey results.

d. Contact resident experts and Army consultants as appropriate.

e. Gather data from ARRCOM functional areas through discussion meetings.

f. Categorize and analyze, as to methods of management, the items which are and those which are not under Item Management.

g. Develop list of potential performance indicators as criteria for comparing alternatives.

h. Analyze data gathered from functional areas and determine significant factors which influence performance.

i. Develop and analyze alternatives for item management alignments.

j. Compare those a' rnatives. (Reference Comparative Analysis.)

k. Develop impacts. Quantify cost and personnel impacts as much as practicable.

l. Develop conclusions and recommendations. (Reference Conclusions and Recommendations.)

m. Prepare final report.

n. Present results to Command.

The basic assumption of the study was that the recommendations, if implemented, would not require a major organizational realignment within HQ, ARRCOM (i.e.--recommendations would involve inventory management only, and not overall ARRCOM).

FACTORS BEARING ON STUDY

The facts and factors bearing on the study were primarily of two categories: administrative, or those which impacted the actual conduct of the study; and, subjective, or those integral to or impacting the performance of materiel management within HQ, ARRCOM.

a. The Administrative factors included:

(1) The study was conducted within the limits of available regular hours, with no overtime.

(2) The study objectivity and impartiality was to be maintained. This was accomplished by forming the Primary Working Group of members from organizations not directly performing item management functions. This then necessitated a certain amount of "education" of the PWG.

(3) Somewhat parochial orientations and understandable bias of the various functional organizations representatives made definitive data gathering difficult.

(4) Research time, both in the location and acquisition of applicable source data and in the physical review of that data proved to be much greater than initially anticipated.

(5) The scope of the study was much broader (e.g., all six elements of inventory management) than indicated by the prior study, which was keyed to "Delivered/Unbilled Shipments Deficiencies."

(6) External limitations, workloads and organizational priorities resulted in severe restrictions on availability both of team members and of administrative support.

(7) Personnel involved in this study and/or contacted during its conduct evidenced competence in their assigned materiel management responsibilities, displayed a conscientious attitude, and except as noted above, were highly cooperative.

b. The Subjective factors included:

(1) Current SM implementations and reorganizations including the further decentralization of HQ, ARRCOM inventory management through the formation of DRSAR-DA.

(2) Current development of the new "ABC System" for integrating ammunition component reporting and loading those items in the NSNMDR through the PMDR to allow CCSS processing.

(3) Basic requirements to comply with ASPR and other regulations.

(4) Implementation of the various recommendations from the prior study on "Delivered/Unbilled Shipments of Deficiencies," some of which are in process and the others assumed to be effected in the near future.

(5) Basic differences in the missions and functions of the various organizational elements of HQ, ARRCOM.

(6) The scope of the overall ARRCOM missions and the diversity of items result in extremely complex organizational interfaces.

(7) The evolution and development of many independent procedures unique to an organizational element and geared to the management of its assigned items and missions, including the utilization and development of ADP processes/systems other than CCSS (e.g.,--the current DRSAR-MA development of a stand-alone process for APE).

(8) The magnitude and complexity of the CCSS itself, and the attendent difficulty in achieving universal integrated understanding or utilization of the full system and processes throughout HR, ARRCOM.

DISCUSSION

a. The complexity of the study subject was recognized at the outset. There was also a strong suspicion that considerable ambiguity and misunderstanding existed among the various HQ, ARRCOM organizational elements in reference to usage of terms, delineation and separation of responsibilities for the different missions and functions, and the utilization and adherence to available standard systems and processes. These suspicions were all supported as the study progressed.

b. The preliminary survey questionnaire served several purposes. Primarily, it gathered data for later comparison and analysis, covering such areas as items managed, who manages the items and how, and differences in procedures and definitions of terms. Results of the survey indicated considerable disparity in the understanding and use of terms. A set of clear definitions, as applied to the study, therefore became a crucial early effort of the Primary Working Group (PWG). The survey also served as an "educational" device for the PWG, providing a good cross-section of information on materiel management activities within HQ, ARRCOM. The survey responses also served as a guide to the PWG as to what additional areas and questions needed to be covered in subsequent research and discussion meetings (Reference Final Report, Appendix F) with representatives of the key functional organizations. The most crucial terms requiring definition were those related to materiel management (e.g. Item Manager, Inventory Manager, Materiel Management, etc.) and clarification of Centralization and Decentralization. Considerable effort was expended in this area, and the backup material can be found in the complete report. Basically, Materiel Management is a broad term covering all aspects of the management of items and material. Item Management is roughly synonomous with Materiel Management, and should be considered a broad or generic term. Unfortunately, colloquial usage varies and there are numerous and simultaneous applications of the term Item Manager to those performing various functions of Materiel Management. These varying functions should be more accurately described by terms denoting the specific areas of materiel management involved. For example, the materiel management functions performed by DRSAR-MM and DRSAR-DA are actually inventory management, and the official (job description, Series 2010) title for the people performing these functions is "Inventory Management Speciali t." But these people are frequently referred to as Item Managers. Similarly, the people from DRSAR-PD, though also often referred to as Item Managers, are actually Production Management Specialists or "Production Managers" (generally engineers and industrial specialists). The people from DRSAR-IL are actually "Case Managers" and should really be performing very little of the inventory management functions.

c. A more difficult area to resolve is that of the terms Centralization and Decentralization. Though singular definitions may be developed for each, in application any condition identified as "centralized" in one frame of reference may paradoxically be identified as "decentralized" at another level or in another frame of reference (e.g., the "centralization" of all conventional ammunition inventory management functions in one organizational element may be considered a "decentralization" of both materiel and overall materiel management functions; with corollaries ad infinitum). The PWG found no singular answer to the definition of centralization. The only resolution to the problem appeared to be arbitrarily establishing an ad hoc definition of centralization as it pertains to this study and in reference to the performance of the six elements of inventory management (i.e., Cataloging, Requirements Determination, Procurement/Production Direction, Distribution Direction, Maintenance Direction, Utilization and Disposal Direction). Backup material and discussion on this can be found in the report. Briefly, centralization is the grouping of all similar management functions within a single organizational element. In this context, current inventory management is basically "decentralized." For the purposes of this study, the following definitions of centralization and decentralization apply:

(1) Centralization. Item/Inventory management under one control; i.e., all item/

inventory managers and their functions are located in and work for one directorate.

(2) Decentralization. Responsibility for the functions of inventory management and items managed are spread among several directorates. Directorates perform all or most of the functions of inventory management for items in their functional area. Item/inventory managers are located in two or more directorates.

d. Another problem encountered by the PWG was in the complexity, variations, and magnitude of materiel management within HQ, ARRCOM. The variations in both items managed and uniquely applicable procedures for their management, as well as basic differences in the missions and functions of the organizational element involved, made quantitative comparisons and analysis difficult if not impossible. Though the PWG expended considerable time and effort in trying to develop useful quantitative data, sufficient comparable data was not available for meaningful quantitative analysis. The study emphasis, by the dictates of the subject matter, was primarily centered upon the qualitative aspects. Even in this regard the complexity and organizational interfaces posed a problem for the PWG. If each variation in procedures, item assignments, and organizational alignment were to be considered as a study "alternative," the list of alternatives would become so long as to preclude analysis. The PWG resolved this problem by reducing the potential alternatives to the minimum - i.e., status quo, further decentralization, further centralization, and total centralization. All variations in item assignments, procedural changes, etc., could then be treated as options or conditions of the basic alternatives. This development is shown in complete report.

e. Assuming status quo to be the condition from which either centralization or further decentralization might evolve, it was necessary to delineate that condition. Considering the dynamic nature of HQ, ARRCOM, the implementation of SM responsibilities including the establishment of the new DRSAR-DA Directorate for conventional ammunition, the assumption that the recommendations from the study on "Delivered/Unbilled Shipments Deficiencies" would be fully implemented, the constant procedural changes such as the development of the new "ABC System" for loading ammunition components into the PMDR/NSNMDR, even status quo is a non-static condition. The final report (Chapter 2) provides a statement of the development of status quo from prior to March 1977 to current condition subsequent to the above actions, or effectively subsequent to October 1977.

f. The four alternatives, including status quo, are then analysed in Chapters 3 and 4. This was done by analyzing, in Chapter 3, status quo as the basic condition/alignment. The remaining options were then analyzed, in Chapter 4, as alternatives to status quo. The analyses address aspects of mission, organization, control, regulations, procedures, personnel, materiel (items), costs and other factors impacting item/materiel management. The comparative analysis of status quo and the alternatives are presented in Chapter 5, with the summary and conclusions of the findings and the study recommendations given in Chapter 6.

g. Though direct references are not always cited in the body of this report, the data and information available in the appendices served as the basis for the analysis, conclusions and recommendations presented herein. The information relative to "centralization/decentralization" and to the definition of terms came mainly from the PWG's research into available literature, prior studies, regulations and other documentary sources. The information relative to missions, functions, procedures, "systems" utilized, personnel and item assignments, and problem areas came mainly from the inputs of the various TSG representatives (primarily those from the key functional directorates involved in or directly interfacing with inventory management).

COMPARATIVE ANALYSIS

Centralized vs Decentralized.

a. Organizational centralization, in the pure sense, is the location of all functions in a single element with a single, vertical line of authority, direction and control. It is rarely applied and generally impractical. Any deviation must be considered to be some form of decentralization, although it may be closer to centralization than it is to total decentralization. Total decentralization is equally rare and impractical.

b. Organizational decentralization can occur in varying degrees and in several different contexts:

(1) Large organizations may require decentralization merely for the sake of dividing the organization into manageable parts or divisions; e.g., most large corporations are organized into major divisions. Each division can function independently of the others since all services and functional specialties are duplicated in each division. This type of decentralization allows for management authority and responsibility to be delegated to lower levels and, thus, shorten lines of communications and help eliminate bottlenecks. However, if an organization has too many divisions, management control will be degraded, and inefficiency results because of duplication of effort, etc. When carried to either extreme of centralization or decentralization, the disadvantages outweigh the advantages; therefore, there is an optimum number of major divisions for any given organization. This optimum point depends upon the size and function of the organization.

(2) Organizations may be decentralized to provide physical dispersion of facilities and/or services into different geographical or functional areas. Decentralization through dispersion of facilities and/or personnel may provide the same advantages and disadvantages discussed in 1b(1) above. Additionally, this type of decentralization can shorten supply and/or communication lines to the customers.

(3) Organizational decentralization may divide the organization into functional elements. This type of decentralization provides the same advantages and disadvantages discussed in paragraph 1b(1) above. Additionally, since all like functions would be performed in one element, division or directorate, a high degree of specialization can develop in the functional areas or in the expertise related to items/products.

c. A "mix" or combination of centralization and decentralization is conceded to be the most practical and generally preferred alignment.

HQ, ARRCOM Organization.

a. Current inventory management of all items normally referred to as standard items is decentralized, and is performed in two separate NICP's, DRSAR-DA (Conventional Ammunition) and DRSAR-MM (Weapons). This decentralization, which is a deviation from required centralized integrated inventory management (AR 710-1), was authorized by The Department of the Army. Basically this was required because the Commodity Command was directed by DOD to provide Single Management for most classes of conventional ammunition, for all armed services (e.g., Army, Air Force, Navy, and Marine Corp). This requires a different type of inventory management than Centralized Integrated Inventory Management directed by AR 710-1 for the Commodity Commands. Inventory Management of DRSAR-MA (APE) and DRSAR-QA (FATE) items, normally referred to as non-standard items (yet they are procured, stocked, stored and issued), is not only decentralized but is manually managed outside of the NICP's and CCSS. This was authorized by ARMCOM Supplement 1, dated 16 October 1975, to AMC Regulation 702-2, dated 27 May 1966, Subject: Quality Assurance Inspection Equipment Design, Supply, and Maintenance. This is in direct conflict with AR 710-1, dated 29 August 1975, Subject: Centralized Inventory Management of The Army Supply System. Also, it was a command decision that DRSAR-PD will inventory manage industrial components that are not end-items within themselves and/or already inventory managed by the NICP's. DRSAR-PD is now in the process of loading these items to the PMDR and the NSNMDR.

b. The command also has a unique situation in supplying industrial components through the field service account (NICP's). These items are production managed and controlled by DRSAR-PD. They have also been recorded in the NSNMDR for production purposes, but production assets will not be recorded in Sectors 5, 6, or 8. If the NICP's receive a demand (MIPR, FMS, or POR) for industrial components, DRSAR-PD will provide the necessary documentation to transfer the stock into the NICP account, and process the customer demand through the CCSS. If the industrial component is not recorded in the NSNMDR, and the command elects to supply the items, DRSAR-PD will add the items to the NSNMDR and process as above.

c. The organization of HQ, ARRCOM for item management is basically decentralized through all the types of decentralization discussed in paragraph 1 above.

(1) The formation of two NICP's, one for ammunition and one for weapons and secondary items, is the type of decentralization discussed in paragraph 1b(1) above. This deviation, i.e., establishing two NICP's in one Commodity Command, was approved by the Department of the Army.

(2) The physical dispersion of item managers into DRSAR-MA and DRSAR-QA is the type of decentralization discussed in paragraph 1b(2) above.

(3) The basic structure of the headquarters is the type of functional decentralization discussed in paragraph 1b(3) above.

Attribute Analysis.

a. An attribute analysis was performed to compare the present HQ, ARRCOM organization for inventory management and the alternatives discussed in Chapter 4. The results of this analysis are summarized below.

Alternative	Weighted Score
Status Quo	+24
A. Further Decentralization	-28
B-1. Complete Centralization	+18
B-2. Partial Centralization	+23

b. An attribute analysis is highly subjective and especially so if an attempt is made to quantify the analysis in seeking to rate or comparatively rank the alternatives. The attributes and performance factors utilized, the weighting given to each, and the rating of the alternatives against these attributes are all subject to personal interpretations. So much so, in fact, that individual interpretations could not only alter, but indeed completely reverse the comparative rankings and results of the analysis. The attribute analysis performed in this study represents the consensus of the Primary Working Group. The full listing of attributes and rating value are provided in Exhibit 1, Attribute Alternative Analysis.

c. Though an attribute analysis is only appropriate as an indicator of relative strength

of alternatives and not as the prime or singular basis for a decision, results of the analysis strongly suggest that:

(1) Further decentralization has such a low score that further consideration of the alternative is unwarranted.

(2) Partial centralization and total centralization have very similar advantages/disadvantages and strengths/weaknesses. However, the relative strengths or weaknesses of the advantages and disadvantages depend upon the degree of centralization and upon the size, type, and mission of the organization. In this regard the analysis indicates that partial centralization is significantly preferable to total centralization.

(3) Status quo is the most desirable alternative, with partial centralization being nearly as desirable as status quo.

Rationale.

a. Tables 1 through 4 of Exhibit 2 provide a summary of the major conditions, advantages, and disadvantages, of status quo and each of the alternatives as discussed in Chapters 3 and 4.

b. Status quo after total implementation (of SM, COCP, the ABC system, and of the recommendations of the "Delivered-Unbilled" Task Force) would provide us with approximately 95% of customer demand fill-and-bill through the CCSS. Although we could fill demands and bill through the CCSS, status quo would not provide total integrated centralized inventory management or a centralized data base of all assigned commodities. Status quo was obviously the most expeditious means of generating customer billing through the CCSS without affecting the existing organizational structure, and/or resolving the disagreement and interpretations of the regulatory requirements of Centralized Integrated Inventory Management. Although current inventory management of all standard supply items is decentralized (in DRSAR-MM and DRSAR-DA), the organizational alignment allows for a high degree of inventory management specialization in these functional areas. Inventory management of non-standard items is decentralized in other directorates. However, these items are generally peculiar to a particular organization or function and are not normally issued through the standard supply system. Instead, these items (APE, FATE, and industrial items and components of production) are managed on an internal basis by the directorate to which the items are peculiar. That is, inventory management in DRSAR-PD, DRSAR-MA, and DRSAR-QA is primarily an inter-divisional service within these directorates and, in the case of DRSAR-PD, not a separately identifiable function which could be easily separated out. Inventory management in DRSAR-QA and MA is a distinct function, however. Having inventory management internal to these directorates (DRSAR-PD, QA and MA) keeps lines of communication between the inventory managers and other personnel in the directorates as short as possible. External demands or interfaces with these inventory managers is the exception rather than the rule.

c. Increased decentralization is not considered to be a reasonable alternative because this would cause unnecessary duplications and increase overall complexity of operations, interfaces, and lines of communications. Also, decentralization of responsibility for item management was cited as a possible root problem addressed by the study on Delivered-Unbilled Shipment Deficiencies. Thus, to advocate further decentralization is akin to advocating exacerbation of a basic problem, and further deviation of regulatory requirements (AR 710-1).

d. Total centralization would cause numerous conflicting problems in operating a Commodity Command NICP under Centralized Integrated Inventory Management as directed by AR 710-1, and operating the Conventional Ammunition Single Manager (NICP) Concept as directed by DOD Directive 5160.65.

Total centralization is not practical due to the difference in Centralized Inventory Management under the Commodity Command Concept, and Conventional Ammunition Single Manager DOD concept.

The disadvantages of total centralization (see Chapter 4) outweigh the advantages, and the alternative is not preferred.

e. Partial centralization as described in paragraph 3b(1)(c), Chapter 4, would provide centralized inventory management in accordance with AR 710-1 and approved deviations, while providing a standard centralized accountable system that would provide the command with a tool to view all materials to perform the command's mission. However, this would be difficult to achieve in the near term time frame, because we do not now have a centralized or total data base of all items assigned to and/or managed by this command.

Partial centralization as described in paragraph 3b of Chapter 4 should provide improved item management of FATE and APE items because this would place inventory management responsibility for these items in the areas with the greatest materiel management expertise. However, there would be some inconvenience in DRSAR-MA and DRSAR-QA because of the physical separation of the inventory management functions from the primary functional responsibilities. Partial centralization has considerable merit and the advantages appear to outweigh the disadvantages. The overall advantage of this alternative would depend upon:

EXHIBIT 1

ATTRIBUTE ALTERNATIVE ANALYSIS

QUANTIFICATION COMPARISON

Attribute Description	Attribute Weight 1,2, or 3	Further Decentral. Rank	Further Decentral. Value	Status Quo (Current) Rank	Status Quo (Current) Value	Further Central. Rank	Further Central. Value	Total Central. Rank	Total Central. Value
1. Management Control	3	-1	-3	1	3	1	3	2	6
2. Item Control	3	-1	-3	0	0	1	3	2	6
3. Standard Procedures	3	-2	-6	1	3	1	3	2	6
4. Inventory Management	2	-2	-6	0	0	1	2	2	4
5. Cost	2	-1	-2	2	4	1	2	-2	-4
6. Reorganization	2	-1	-2	2	4	1	2	-2	-4
7. Personnel	2	-1	-2	1	2	1	2	1	2
8. Expertise	2	2	4	1	2	0	0	-1	-2
9. Turmoil	2	-1	-2	2	4	1	2	-2	-4
10. Training	2	-1	-2	1	2	1	2	2	4
11. Coordination	1	-2	-2	0	0	1	1	2	2
12. Duplications	1	-2	-2	0	0	1	1	2	2
TOTAL VALUE	25		-28		+24		+23		+18

WEIGHT SCALE
3=Critical
2=Important
1=Desirable
0=Not Important

RANKING SCALE
+2=Enhances to High Degree
+1=Enhances Attribute
0=Neutral or Does Not Possess Attribute
-1=Hinders Attribute
-2=Hinders to High Degree

TOTAL VALUE RANGE
(25W) x (+2R)= +50 Max.
(25W) x (-2R)= -50 Min.
"Value" Range= 100 Points

(1) How much improvement in item management of FATE and APE items could be obtained by centralization into the NICP. This in turn would depend upon the efficiency of the standard NICP item management procedures/systems applied to the items. Simply transferring the functions and/or personnel with no change in current procedures, clearly, would provide little improvement or advantage.

(2) How much DRSAR-MA and DRSAR-QA would be inconvenienced by the physical separation of their inventory managers. This would depend upon how much coordination with the NICP personnel would be required, etc.

(3) How much cost would be involved in entering these low-demand items in the NSNMDR and carrying them in the "inventory."

f. Regardless of the comparative advantages and disadvantages of centralization as discussed in this study, consideration must be given to the Department of Army decision that Commodity Commands would organize and manage assigned commodities within an NICP structure and utilizing centralized integrated inventory management (AR 710-1). The following must also be considered:

(1) ARRCOM Supplement 1 (dated 16 October 1975) to DARCOMR 702-2 (dated 27 May 1966), Inspection Equipment Design, Supply and Maintenance; which provides for DRSAR-QA and DRSAR-MA inventory management of FATE and APE items external to the NICP. This appears to conflict with requirements of AR 710-1 (dated 29 August 1975), Centralized Integrated Inventory Management.

(2) The implementation of DOD Directive 5160.65, Single Manager for Conventional Ammunition, which established DRSAR-DA as a second NICP at HQ, ARRCOM; i.e., separate from the existing DRSAR-SM NICP.

Summary.

a. The advantages and disadvantages of centralization versus decentralization depend upon the size and function of an organization and how it is to be centralized or decentralized (e.g., by function, by item/product line, by geographic or physical location, by customer served, etc.).

b. Neither extreme, further decentralization nor total centralization, is practical.

c. The present (Status Quo) organizational structure of HQ, ARRCOM provides many advantages over the two extreme alternatives (A and B-1) considered, and apparently works well the majority of the time. Status quo assumes full implementation of SM, of the COCP and ABS system, and of the "Delivered-Unbilled" study recommendations; and rates highest for the near term.

d. Partial centralization (Alternative B-2) involving FATE, APE, and those industrial components of production which are supplied to customers, would satisfy regulatory requirements (AR 710-1) for Centralized Inventory Management. This alternative compares favorably with status quo, and rates highest as a potential goal for the longer term.

EXHIBIT 2
SUMMARY OF ALTERNATIVES

TABLE 1b

SUMMARY OF "STATUS QUO"

ADVANTAGES

- CCSS for bulk of issue items, and standard ID components. (NSNMDR Items)
- Promotes individual item expertise.
- Responsibility keyed to specialization by functional use and items.
- Minimal retraining required in NICP's.
- Minimum personnel turbulence.
- Minimum reorganization.
- Minimum procedural revisions.
- Minimum cost impacts.
- Balance of internal and external lines of communications.

DISADVANTAGES

- IL performing some "IM's" functions.
- FD performing some "IM's" functions.
- Control problems:
  - Internal coordinations.
  - Non-standard accountability.
  - System-reject distribution.
- Training required for CCSS users outside of NICP's.
- Multi off-line procedures.
- Retains some duplication.

TABLE 2b

SUMMARY OF "FURTHER DECENTRALIZATION"

ADVANTAGES

- Maximum functional specialization by category of items (micro efficiency).
- Less levels of management.
- Procedures customized to missions.
- Individual responsibilities most identifiable.
- Shortest external lives of communication (with customers).

DISADVANTAGES

- Maximum continuing training requirement.
- Most complex internal communications (within HQ organization).
- Potential increase in duplication (administration & supervision; MCN/NSN item assignments).
- Management control reduced.
- Reduces uniformity of policies.
- Multi off-line procedures.
- Minimum standardization (of procedures. system, etc.).
- Contrary to regulations on integrated commodity management.
- Control problems:
  - Non-standard accountability.
  - System-reject distribution.
- IM functions in many Directorates.

- Minimum automated item control.
- Possible increase in personnel requirements.

TABLE 3b

SUMMARY OF "TOTAL CENTRALIZATION"

ADVANTAGES

- Maximum utilization of CCSS/ADP.
- Consistency of procedures.
- Unity of control/policies.
- Elimination of duplication.
- Maximum cross-fertilization for IM's.
- Shortest internal lines of communications.
- Least overall training required.
- Improves regulatory compliance for integrated inventory management.

DISADVANTAGES

- Maximum turmoil (personnel).
- Maximum reorganization.
- Maximum cost to implement.
- Maximum retraining (NICP's).
- Contrary to SM concept with establishment of DRSAR-DA).
- Reduces "specialization" (re:items).
- Magnitude unwieldly, blocks control.
- Management "Layering"/Increase.
- Longest external lines of communication.
- Possible increase in personnel requirements.

TABLE 4b

SUMMARY OF "PARTIAL CENTRALIZATION"

ADVANTAGES

- Reduce duplication.
- More standardization of procedures.
- Less fragmentation of IM's.
- Reduce CCSS training.
- Reduce overall (internal/external) lines of communications.
- Increase utilization of CCSS/ADP.
- Improve unity of control/procedures.
- Minimal reorganization.
- Minimal cost impacts.
- Minimal personnel turbulance.

DISADVANTAGES

- Reduce specialization (Re:items).
- FD performing some "IM's" functions.
- Some CCSS/IM training required outside of NICP's.
- Possible increase in personnel requirements.
- Retains some duplication.
- Control problem: System-reject distribution.

CONCLUSIONS AND RECOMMENDATIONS

Discussion of Conclusions.

a. General.

(1) Centralization (e.g., of inventory management functions, and the performing personnel) provides the opportunity to standardize procedures, to improve efficiency by increased use of ADP systems, to maintain central control, and to provide management with a centralized asset and requirement posture within an acceptable time frame.

(2) Some degree of centralization is required; e.g., for inventories to be controlled at the national (NICP) level.

(3) Decentralization by delegation of authority to lower levels allows procedures and /or systems to be customized to the needs of each organizational element and may shorten supply and/or communication lines for day-to-day operations, since management decisions would be made at lower levels. Decentralization also fosters the maintenance of organizationally unique, local inventory records within each organization for maximum accessability at the lower levels.

(4) Some degree of decentralization may be required to prevent organizations from becoming too large to be managed effectively.

(5) Neither total centralization nor total decentralization is workable except in rare situations. A "mix" is usually best.

b. In Terms of HQ, ARRCOM Structure.

(1) The current structure of HQ, ARRCOM for inventory management is a combination of centralized and decentralized organization.

(a) Weapons, secondary items and related packaging materiels are managed (centralized) in DRSAR-MM, an NICP, under formal integrated inventory management procedures.

(b) Ammunition end items and related packaging materiels are managed (centralized) in DRSAR-DA, an NICP, under formal integrated inventory management procedures.

(c) APE items are managed (centralized) in DRSAR-MA by a stand-alone system outside of the NICP's; but under Status Quo (fully implemented) DRSAR-MA will formally inventory manage those items for which customer demands are received, and process the demands through the CCSS.

(d) FATE items are managed (centralized) in DRSAR-QA by another stand-alone system out [illegible] of the NICP's; but under Status Quo (fully implemented) DRSAR-QA will formally inventory manage those items for which customer demands are received, and process the demands through the CCSS.

(e) Industrial materials and components for production are managed (centralized) in DRSAR-PD outside of the NICP's. This is production management, and not integrated inventory management per se.

(f) The composite is decentralization.

(2) If assigned commodities are inventory managed outside of the NICP, or a commodity command has more than one NICP, integrated materiel inventory management, per se, is decentralized. (This is not to be confused with centralized versus decentralized methods of Integrated Inventory Management to be employed by the NICP's for each individual item of assigned commodities, i.e., the option of authorizing local procurements on NICP items.)

(3) In HQ, ARRCOM only DRSAR-MM, DA, QA, and MA have assigned personnel performing formal integrated inventory management as their primary job. All others have other primary missions/functions, and any functions performed which are related or similar to integrated inventory management (NICP) functions are only secondary and in support of accomplishment of their primary responsibilities.

(a) APE and FATE items are procured, stocked, stored and issued, through the logistics supply system, to Proving Grounds, Industrial Plants (GOGO, GOCO, and Commercial), Depots, FMS and MIPR's; though not in accordance with Integrated Inventory Management/CCSS procedures.

(b) Under Status Quo, DRSAR-IL might also continue to "inventory manage" some items and process them through the CCSS. Normally, these are items that DRSAR-IL had agreed to supply on FMS cases, but for which an existing inventory manager could not be located elsewhere in the Command. Under some conditions the Command has been directed by higher headquarters to supply FMS case items not managed by this Command.

(c) Industrial material and components are production managed by DRSAR-PD and, to some degree, some of the elements of integrated inventory management are applied. DRSAR-PD has recorded in the NSNMDP approximately 1,000 of the approximately 10,000 industrial components and materials utilized in the production of commodities (ammunition and weapons) assigned to this Command. These items are not normally issuable items or assigned an MSN or MCN, and are managed through production. The assets are not picked up in the NICP's accounts. These items are not to be confused with weapons repair parts, ammunition maintenance items or ammunition industrial components that [illegible] end items within themself (i.e., fuzes). These later items are managed by the NICP's. The industrial components now being loaded in the

NSNMDR by DRSAR-PD are not being loaded for inventory purposes, but are required to properly generate PWD's from the CCSS in support of the production management cycle. Also, under status quo, DRSAR-PD will inventory manage those industrial components for which customer demands are received, and process the demands through the CCSS.

(4) Such drastic measures as abolishing directorates and creating new ones is neither necessary nor desirable. The positive effects (advantages) of total centralization could be approximated simply by moving all formal inventory management functions to DRSAR-MM and DRSAR-DA. Total centralization (i.e., merging all inventory management into a single NICP) is impractical due to differences in accounting and processing for centralized inventory management under the commodity command concept (AR 710-1), and for Single Manager conventional ammunition under the DOD concept (DOD Dir. 5160.65). DRSAR-DA need not be re-merged with DRSAR-MM, and the continued separation provides a means of effectively implementing DOD Dir. 5160.65 (SM). Also, although DRSAR-PD has "Production Managers", they are performing only a portion of the inventory management functions on a part-time basis, in support of the production mission, and integral to their other responsibilities. These personnel should not transfer to the NICP's, and production industrial materials should not be managed in the NICP unless the item is sold or supply issued.

(5) Movement of item management functions from DRSAR-PD to an NICP organization would provide no significant benefit because other organizations generally do not require access to their production inventory management data, and the production components and materials are not normally sold outside the command. Additionally, this would physically separate the production inventory data from the people who are normally the only ones who need access to it, and would increase the workload in the NICP organizations. Industrial components are not procured, stocked and stored for issue through the logistical supply system, although DRSAR-PD does procure and issue for FMS and MIPR's on request. Industrial components are normally procured for the production of end items, and are picked-up on the Production Industrial Accounting System and not stocked for issues through the logistical supply system.

(6) DRSAR-PD manages the procurement execution and production of end items; and this involves components breakout (requirements determination for production), procurement execution/production direction for components and industrial supplies, and some form of stock control or scheduling to insure that these components and supplies are available at the right place, at the right time, and in the right quantities for LAP or final assembly. However, this is not "inventory management" in the same sense as inventory management is performed in an NICP. Formal inventory management in an NICP involves full performance of the six elements of integrated inventory management within regulatory requirements, and includes worldwide assets knowledge and accountability of field-issuable items from the field issue account. Production inventory management or stock control in DRSAR-PD, on the other hand, involves procurement execution to provide industrial materials and components needed to meet authorized production schedules. The inventory accountability of production stocks is at and by the production facility. That is, DRSAR-PD primarily provides a production/procurement execution function, not a stock, store and supply operation. Once items are assembled and accepted into the field service inventory, then an NICP inventory manager becomes responsible, and DRSAR-PD is no longer directly involved. Thus, moving the inventory management of industrial components and supplies to an NICP would serve no useful purpose and, in fact, would be a hinderance.

(7) Under either Status Quo or Partial Centralization, if the Command makes a decision to supply industrial components to customers (through the NICP's), it should be the responsibility of the NICP to inventory manage the item in the NICP account, including cataloging and recording the item in the NSNMDR if it has not been previously recorded. If it has been recorded, it should be the NIPC's responsibility for recording the proper NICP inventory manager in the NSNMDR analyst code (ANAL-CD) sector.

(8) To differentiate between normal supply items and industrial components in the NSNMDR/CCSS, there should be a method/procedure provided to identify industrial components; and whether it is production managed only or if it is also being inventory managed by the NICP's. This could be accomplished by utilizing a one (1) position code in the ALFU portion (last 5 positions) of Sector-ØØ of the NSNMDR.

(9) Orders for non-standard, non-NICP items through FMS and MIPR are not efficently processed. The cause of this problem is basically:

(a) These items are not recorded in the NSNMDR and therefore will not process through the CCSS. Thus, they must first be loaded to the data base with an MCN (causing a delay of up to two weeks), or processed off-line.

(b) There is a general lack of training, experience, and SOP's for sales of non-standard items. Also, there is a general lack of knowledge in interface areas; e.g., CCSS, cataloging, etc..

Summary of Conclusions.

a. Further decentralization is not a viable alternative because it would result in increased personnel costs and reduced controls. Also, decentralization of responsibility was a root problem addressed by the "Delivered-Unbilled" Task Force study. Thus, to advocate for the decentralization is akin to advocating exacerbation of the basic problem, and conflicts with regulatory requirements for integrated inventory management of logistics supply items (AR 710-1).

b. Full centralization would result in maximum turmoil in organization, personnel and cost, and is contrary to current DOD concepts which resulted in establishment of DRSAR-DA to support SM requirements. Total Centralization is not considered to be a viable alternative.

c. It appears that the present organization benefits from both centralized inventory management of those standard items which require central NICP control and from the decentralization (physical dispersion into functional areas) of some personnel performing some inventory management functions for the management of industrial materiels, tools-of-the-trade used in production, and related support items.

d. As indicated in Chapter 5, continuation of the current (Status Quo) ARRCOM organization for inventory management is the most viable near-term alternative. It is noted that the concept of this alternative assumes total implementation of the approved recommendations of the "Delivered-Unbilled Shipments Deficiencies" study. This has not occurred as yet. The concept also assumes full implementation of COCP, the ABC system, and SM (DRSAR-DA). When fully implemented, the current alignment will provide an estimated 95% of demand fill-and-bill through the CCSS. It will not provide for centralized accountability or a centralized data base of all items assigned this Command to inventory manage through the NICP's.

e. Partial Centralized Inventory Management, as described in Chapter 4 paragraph 3b (1)(e) and required by AR 710-1 (with approved deviations), has high potential for the long term. Although Partial Centralization might be our goal, we should continue under the current alignment until inventory managers could be properly trained or replaced to perform the requirements. At the present there should be a continuous exerted effort to get all "demand" items assigned an MCN and recorded in the NSNMDR. This would minimize subsequent transition efforts for moving all supply/issuance items under the control of the NICP's.

Impacts.

a. Facilities requirements will not significantly change under any alternative and, therefore, are not an impact factor.

b. Overall HQ, ARRCOM personnel requirements and average grade will not significantly change as a result of any alternative.

c. Personnel actions (transfers) associated with either of the preferred alternatives, i.e., continuation of current alignment or partial centralization, are not significant (estimated at approximately 5 spaces).

d. Training requirements associated with either of the preferred alternatives (i.e., Current Alignment and Partial Centralization) are commensurate with those required under implementation of the recommendations of the "Delivered-Unbilled" Task Force.

e. Although cost impacts were indeterminate, the two preferred alternatives should be approximately equal to each other and significantly less than either of the extremes (i.e., Total Centralization or Total Decentralization). Loading and maintaining additional items in the NSNMDR, and training in CCSS procedures will be the two most significant cost impacts.

Recommendations. a. Retain present HQ, ARRCOM organizational structure overall, specifically continuing current alignment for materiel management.

b. Transfer DRSAR-PD industrial components to DRSAR-MM and DRSAR-DA, as appropriate, only for management of sales/demands or as required for Renovation.

c. Retain management of DRSAR-PD industrial components in DRSAR-PD for all "Production" inventories.

d. Assign NICP inventory managers to manage any FATE or APE items and industrial components supplied through the NICP's.

e. Record, with MCN/NSN, all FATE and APE items into the NSNMDR, including appropriate storage locations data, as "demands" are received.

(1) Initiate action to correct, with the assigned MCN/NSN, any records outside of the Command, (e.g., TM's, supply bulletins, etc.).

(2) Establish regulatory loan procedures for FATE and APE items on loan and returnable with accountability through CCSS.

f. DRSAR-IL should under no circumstances be recorded or act as Inventory Manager for any item (no MCN/NSN actions by DRSAR-IL).

(1) DRSAR-IL should "clear" themselves of all previously "loaded" (approximately 300) item responsibility, transferring all items to DRSAR-MM and DRSAR-DA as appropriate.

(2) DRSAR-IL should henceforth offer/accept and handle, in cases, only items assigned to this command, unless specifically directed by higher headquarters, and then process these "non-ARRCOM-assigned" items manually off-line.

g. Standard procedures should be developed for all item managers regardless of location throughout the Command.

(1) CCSS procedures, when applicable, must be adhered to.

(2) Very specific standard procedures should be developed for non-standard items, especially those which do not have NSN's or MCN's, which are being sold through DRSAR-IL and MIPR's.

(3) Establish and enforce standard procedures for all "off-line" (manual and non-CCSS) transactions.

(4) Process all "non-standard items off-line unless the item has been assigned an MCN/NSN and properly loaded to the NSNMDR.

(5) Provide guidance, procedures, and training of all item managers for processing sales transactions, especially for managers of non-standard items.

(6) All formal item cataloging should be accomplished by either DRSAR-MM or DRSAR-DA, as appropriate, in coordination with DRSAR-MA (for initiation and approval of DRSAR Form 19's when required).

(7) All MCN assignments should be cleared through, and all new NSN's should be requested by, DRSAR-MM in coordination with DRSAR-MA.

h. No customer demand (Army external) orders will be processed for any item for which ARRCOM is not or cannot be assigned as PICA, or unless ARRCOM is the SICA and has received formal procuring authority for the item.

(1) Cease customer order acceptance, procurement, and sales of items not assigned to ARRCOM, unless specifically directed by higher authority; and then process these items manually off-line when acceptance is directed. Specifically cease all sales/management of other PICA's items.

(2) A thorough screening through DLSC should be accomplished on all items for FMS cases and MIPR's to insure that this Command is not buying, for resale, items which are managed (as PICA) by another Command.

i. Clarification of AR 710-1 should be obtained in the question of the application of formal Integrated Inventory Management (NICP) to "industrial" items.

j. Fully implement the approved recommendations of the study on "Delivered-Unbilled Shipments Deficiencies," including full implementation of the COCP.

k. Partial centralization, as described in paragraph 3b(1)(e), Chapter 4, should be considered for separate future study subsequent to "fully implemented" actions under current alignment. This future study, if performed, should specifically address:

(1) Transfer of personnel and items into the appropriate NICP to bring all formal inventory management into the CCSS and NICP Centralized Inventory Management environment.

(a) Transfer DRSAR-MA's APE Inventory Management (items and personnel) to DRSAR-DA.

(b) Transfer DRSAR-QA's FATE Inventory Management (items and personnel) to DRSAR-MM and DRSAR-DA as appropriate.

(2) Definitive evaluation of staffing requirements for DRSAR-MM and DRSAR-DA.

EXHIBIT 3

SUMMARY OF LITERATURE REVIEW

Summary of Literary Review Conducted Concerning the Relative Advantages and Disadvantages of Centralization and Decentralization(1).

PROBLEM: To determine the relative advantages and disadvantages of centralization and decentralization in organizations similar to HQ, ARRCOM.

DISCUSSION:

1. The literature listed at TAB A was reviewed for discussion of the above subject.

2. The overall management organization for industry was basically divided into three categories:

(a) Line-organization or centralized. In this organization the line of authority passes directly from the boss to the various subordinate executives of various activities to the lowest level. The flow of the instruction or authority can be traced, unbroken, from the lowest level to the boss. This is used in small businesses.

(b) Functional organization or decentralized. Managerial activities are divided so that each head, from the assistant superintendent on down, has as few functions as possible and is able to become a specialist in these. Authority from top on down is delegated according to functions. The worker level takes orders from several supervisors in regard to the particular function over which the supervisor has control.

(c) Line-staff organization or partial decentralization. Functional staff departments are established to advise, serve, and work through line foremen as well as the organization. The line of authority flows through the staff from top to bottom; however, this is clear cut and undivided delegation of authority. This is the overall organization of HQ, ARRCOM.

3. The organization of the staff section is further classified as centralized and decentralized by function.

4. In the simplest sense of centralization, only one staff will perform a given function such as research, inventory, etc.. This staff may be subdivided by project or speciality field; however, all these functions for the organization will be in one staff agency.

5. In the simplest form of decentralization, each staff agency will perform all functions as they pertain to the overall activity of that staff agency. This more closely fits the current organization of this headquarters, i.e., functional directorates.

6. There exists a disparity on terms among the texts on the terms centralization/decentralization in that centralization of functions is decentralization of management and decentralization of functions can be centralization of activities. This was resolved in context of the study. The study group charter dealt with centralization/decentralization of item/inventory management or functions, thus only those items relative to centralization or decentralization of functions were considered. The delegated authority to accomplish the function is considered inherent with the function.

7. The degree of centralization can and usually does vary within industry depending upon objectives of the company, its size, etc. An example often cited was the accounting section, which is usually centralized regardless of the decentralization of the rest of the functions.

8. Most authors dismissed the extremes of centralization/decentralization summarily as unworkable in all but rare cases. The exception being total centralization of functions within small businesses.

9. The basic advantages listed for centralization were as follows:

a. Duplication of functions is minimized or eliminated, since all like-type functions are centralized, and generally only one agency or staff section performs a given function.

b. Performance or non-performance of duties is easily traced. Only one section performs a function, thus the results are readily identified.

c. System discipline (ADP or manual) is easily maintained. One supervisor insures consistency of operation.

d. There is unity of control over a function. There are no overlapping responsibilities.

e. Fastest overall reaction to a given problem. Since only one staff agency has to react to a functional area, the time lost in coordination is eliminated. The priority of a project is consistent in the staff.

f. Most efficient use of ADP capability The computer summarizes and works large batches of data and prepares fewer reports. Less internal routing and less print time.

g. The volume justifies hiring specialists at the higher level of staff functions, but allows the hiring of less specialized personnel at lower levels as they have the guidance and constant supervision of a specialist.

h. More talented personnel are easily identified as their contribution to the overall effort is easily identified.

10. The disadvantages to centralization were as follows:

a. There is a lack of specialization at the lower levels as each staff element must perform the same function on a wide variety of conditions.

b. It is difficult to place equal emphasis on several projects. There is a tendency to rank projects within a single agency.

c. Managers are overladen with matters that require their personal attention. All inquiries come to a single agency and must be reacted to individually.

d. Managerial ability is not as well developed at lower levels. Since direction is unified in a staff section, the capability of lower managers is overshadowed by that of the staff chief.

e. Limited depth of operation. The loss or absence of an individual can have a broader effect in the organization.

f. Greater development of bureaucracy. A centralized staff tends to develop layers of managers due to its sheer size.

g. Does not fully utilize the capabilities of ADP equipment. Computers are capable of sorting and manipulating data into small specialized areas. This capability is not normally utilized in centralized staff agencies.

11. The basic advantages listed of decentralization were as follows:

a. Allows for more specialization at the lower levels. Since each staff section performs a function as it relates to their area of responsibility, specialization can develop.

b. Managers develop broader abilities as they manage several functions.

c. Equal priority can be given multiple projects.

d. Managers have more first-hand knowledge of problems. Minor problems are easier to identify as the staff agency has a function only as it applies to them.

e. Greater probability of innovation procedure being developed. There procedures can be developed and debugged in one staff agency prior to full implementation agency wide.

f. The organization is better able to adapt to the absence of an individual.

g. Decisions are placed at a lower level closer to the situation.

h. Problems can be identified by product and are less apt to affect the total organization.

12. The disadvantages listed for decentralization were as follows:

a. Difficult to enforce system discipline.

b. Overlapping managerial responsibilities can develop into internal problem with adverse effect at the production level (or too many bosses).

c. Functions are duplicated in each staff.

d. Coordination of the overall effort can be difficult at the top level due to the number of staff agencies that must be dealt with.

e. It is difficult to fix responsibility for poor performance at the functional level because many people may be performing identical functions.

f. Not as responsive to general functional problems.

g. Management not as consistent as centralized procedures.

13. The overall conclusion of most texts was that decentralized operations were the most effective and efficient. ADP becomes essential in a decentralized operation to allow timely responses to a condition or, as stated in Murdick and Ross in reference to computerized system, "It is this centralized control that permits decentralized operations."(8)

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AFLC'S NEW CONCEPT IN MANNING CENTRAL PROCUREMENT ACTIVITIES

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INTRODUCTION

In the last half of 1975, a new system for determining procurement manpower requirements was employed within five Air Force Logistics Command (AFLC) central procurement activities located at AFLC's Air Logistics Centers (ALCs). This procurement manpower management system, known by its computer program identifier, "E841," was developed and employed to accomplish three goals: (1) forecast manpower to reflect both workload fluctuations and policy and procedural changes within the procurement environment; (2) provide data on the effectiveness of personnel in awarding contracts; and, (3) be of practical use to managers who are not statisticians or manpower specialists. Although these three objectives were worthy unto themselves, the main thrust behind E841's development was to answer the question, "How many people does it take to do the procurement job in AFLC?" This was no simple question!

The procurement activities within AFLC obligated $3.8 billion in FY 76 to buy supplies and services for the Air Force, other government activities, and for those foreign governments participating in the Security Assistance Program. The E841 system had a real job ahead of it - to determine the necessary number of procurement specialists for this multi-billion dollar workload. If successful, it would mean that "paper-pushers" could manage manpower using production management techniques long ago developed for manufacturing concerns. Subjective judgments and negotiations would no longer be the only way to arrive at manpower requirements for support and service organizations.

BACKGROUND

Prior to E841, procurement manpower requirements were developed by virtue of a formula that was predominantly driven by the dollar value of past contract awards. Hence, the larger the dollar volume of experienced business, the greater the manpower requirement for the future. This procedure was deficient for several reasons. First, it was reactive - not forward looking. For example, in FY 7[illegible] procurement was manned on FY 74 experience, not on forecasts for FY [illegible] workload. Second, the contracts that consumed procurement's time due to volume, technical complexity, or because of negotiation difficulties often had relatively low dollar price tags which precluded their being given proportionate consideration in the manning formula. An additional defect of the previous manning methodology was that management had no way to determine whether their people were performing efficiently; that is, considering the volume and complexity of workload, how did contract output relate to current manning?

The initial impetus to develop a system to enable procurement to match hours spent with contracts written was AFR 25-9, Air Force Participation in the Defense Integrated Management Engineering Systems (DIMES) Program, which dealt with DOD productivity. On 5 July 1974, the AFLC Deputy Chief of Staff for Procurement and Production gave the Warner Robins ALC Procurement Director the responsibility for developing an internal management system to achieve the objectives under AFR 25-9 and to strengthen the credibility of procurement's manpower requirements computation through the use of a logical, auditable methodology. The personnel responsible for the efforts to attain these objectives were Mr. Paul Jarrett, Mr. Sam Que[illegible], Mr. Bill Bennett, and Mr. Ray Benefield, all from WR-ALC Procurement, and

Mr. Harvey Brown from the WR-ALC Management Engineering Team.

Initial testing of the newly developed E841 system was completed in June 1975, with Command implementation during August. The original objectives were expanded during development of the program to emphasize measurement of personnel efficiency in awarding contracts and to reflect workload fluctuations and changes in procurement policies and procedures.

SYSTEM FUNDAMENTALS

To be responsive to the AFLC procurement environment, the manpower system was tied to the heart of procurement's business, that is, the type of contract issued and the unique tasks involved with each award. The "tool" used to accomplish this was a matrix from which buyers could select one of 23 different contract types and up to 55 different complexity variables to describe the events that occurred during the awarding of a contract. An example of the form with which buyers reflect these choices is shown in Figure 1. Detailed time standards were developed for each basic contract type and each complexity element by the AFLC Management Engineering Teams, in conjunction with procurement personnel. These standards are the vehicle for translating procurement activity into earned man-hours and are the first of three variables necessary for determining future procurement manpower requirements. The second variable is a series of correlation factors which are the ratios of each of the 23 contract types to the total number of purchase requests received during the previous 12 months. Procurement's expected number of contracts is then forecast by applying these correlation factors (ratios) to the third variable, the expected volume of future purchase requests. The final step in the process is to multiply the expected number of contracts by variable #1, the historical standards for each contract type. The outcome of this process gives procurement managers a direct manpower requirement developed from the complexity and volume of their actual business.

To maintain the reliability of the system, the detailed standards that drive E841 and the workload data submitted by the procurement buyers are periodically validated. For instance, each buyer is provided with criteria as to when and how the various complexity factors are to be applied. Audits by Headquarters procurement personnel insure that these criteria are applied consistently across the Command. The standards themselves are also audited by the Management Engineering Teams, in conjunction with procurement personnel, to insure that the current procurement environment is realistically reflected. The results of this program accomplish the end for which it was designed - the identification of actual manpower requirements to accomplish the procurement workload.

The new system also makes performance measurement possible through comparison of the standard hours that a buyer, section, branch, etc., actually earns to total available hours. For instance, if tasks were accomplished in less than standard hours, the accomplishments would reflect efficiency or vice versa. An analysis of this efficiency can lead to understanding the effects of workload cycles, policy and procedure changes, absenteeism, and numerous other factors on contract output.

ADVANTAGES/DISADVANTAGES

The principle advantage of the new system versus the old has already been discussed - the new system matches manpower to the projected volume and complexity of procurement's business rather than to an unrealistic indicator, such as past contract dollars. A second advantage is its common-sense useability by management. For instance, by highlighting peculiarities in contracting techniques (complexity elements), the system can indicate to managers that one organizational subdivision may be eliminating steps or procedures that another is accomplishing. This visibility could lead to new, improved procedures or possibly to corrections of deficient procurement practices.

The new system also enables management to adjust their manpower forecasts based on knowledge of workload or procurement policy changes. If a procurement policy change affects the complexity of placing con-

FIGURE 1

FREQUENCY ANALYSIS INPUT FORMAT

COMPLETION

	RECORD TYPE	ACTION CODE	BRANCH	SECTION	BUYER	PIIN - SUPP PIIN	MMC	TYPE INSTRUMENT	*TYPE FUNDS*	NO. OF PRs/AMDs	NO. OF CLINS
CARD COLUMN	1	2	3	4	5	6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	25 26	27	28	29 30 31	32 33 34 35 36
	G	E									

*TYPE FUNDS CODE

E = Engineering
S = Stock
I = Investment
D = Depot Maintenance Industrial (DMIF)
O = Other

CANCELLATION: "ENTER E IN COL 1"

RETURN: "ENTER F IN COL 1"

	RECORD TYPE	ACTION CODE	BRANCH	SECTION	BUYER	PR/AMENDMENT NUMBER		MMC	TYPE INSTRUMENT	*TYPE FUNDS	NO. OF PRs/AMDs	NO. OF PR LINE ITEMS	DATE CANCELLED/ RETURNED	MILESTONE	CYCLE
CARD COLUMN	1	2	3	4	5	6 7 8 9 10 11 12 13 14 15 16 17 18 19 20	21 22 23 24	25 26	27	28	29 30 31	32 33 34 35 36	37 38 39 40 41	42 43	44
		E													

COMPLEXITY ELEMENTS

MULTIPLE OCCURRENCES: (Annotate number of changes or PASs in applicable box. If less than "10" occurrences, prefix with zero, i.e. "01")

[45-46] (23) REQUIREMENT CHANGE AFTER SOLICITATION

[47-48] (40) PREAWARD SURVEY (PAS) REQUIRED

[49-50] (41) NEGATIVE PREAWARD SURVEY

SINGLE OCCURRENCE: (Annotate "X" in applicable box.)

(01) ☐ ASPR 1-2100 ADVANCED PROCUREMENT PLAN
(02) ☐ AFLCM 66-8 PREPROCUREMENT REVIEW
(03) ☐ MANUAL PURCHASE REQUEST/MANUAL AWARD
(04) ☐ REPAIR/PDM/ACI/IRAN/MOD/ENGINEERING
(05) ☐ PROTOTYPE/FACI/KITPROOF/PROVISIONING
(06) ☐ FIRST ARTICLE/PRODUCTION ITEM
(09) ☐ SOLE SOURCE/SELECT SOURCE
(10) ☐ SMALL BUSINESS COORDINATION
(11) ☐ PRICING ARRANGEMENT OTHER THAN FFP
(12) ☐ TWO-STEP PROCUREMENT
(13) ☐ MULTI-YEAR PROCUREMENT/CONTRACT
(14) ☐ INDEFINITE QUANTITY
(15) ☐ GOVERNMENT FURNISHED EQUIPMENT/PROPERTY
(16) ☐ WARRANTY DETERMINATION REQUIRED
(17) ☐ VALUE ENGINEERING DETERMINATION REQUIRED
(18) ☐ D&F APPROVAL - ABOVE CONTRACTING OFFICER
(19) ☐ AFLCR 70-15 PROCUREMENT PLAN REQUIRED
(20) ☐ AFLCR 70-14 BRIEFING REQUIRED
(21) ☐ NO RESPONSE RECEIVED
(22) ☐ PREQUOTATION CONFERENCE REQUIRED
(24) ☐ BID SETS REQUIRED - NOT PREVIOUSLY ANTICIPATED
(25) ☐ LIFE CYCLE COSTING UTILIZED
(26) ☐ AWARD FEE FEATURE UTILIZED
(27) ☐ TRANSPORTATION EVALUATION REQUIRED
(28) ☐ FORMAL SOURCE SELECTION UTILIZED
(29) ☐ SECURITY REQUIREMENTS (DD FORM 254)
(30) ☐ TECHNICAL EVALUATION REQUIRED
(31) ☐ COST/PRICE ANALYSIS/NEGOTIATE & PNM
(32) ☐ AUDIT/DD FORM 633/NEGOTIATE & PNM
(33) ☐ SURPLUS BUY ITEM
(34) ☐ FOREIGN MILITARY SALES CASE
(35) ☐ PRENEGOTIATION BRIEFING - CC OR ABOVE
(36) ☐ MISTAKE IN BID
(37) ☐ PECULIAR TERMS AND CONDITIONS
(38) ☐ ASPR/AFLC DEVIATION REQUIRED
(39) ☐ OFFBASE NEGOTIATIONS REQUIRED
(42) ☐ SBA REFERRAL FOR COC PROCESSED
(43) ☐ DETERMINATION - OTHER THAN LOW BIDDER
(44) ☐ JUDGE ADVOCATE REVIEW REQ.
(45) ☐ PPC ADMINISTRATIVE REVIEW REQUIRED
(46) ☐ EEO COMPLIANCE/HAF-LGP(AR)701
(47) ☐ LOCAL/AFLC MANUAL APPROVAL REQUIRED
(48) ☐ PROTEST BEFORE AWARD
(49) ☐ NOTICE OF AWARD ISSUED
(50) ☐ NOTICE TO PROCEED ISSUED
(51) ☐ BILATERAL DOCUMENT - NOT PREVIOUSLY ANTICIPATED
(52) ☐ DD FORM 350/SYNOPSIS REQUIRED
(53) ☐ POST AWARD CONFERENCE REQUIRED
(54) ☐ TYPE-SOLICITATION IN BUYING DIVISION
(55) ☐ TYPE CONTRACTUAL DOCUMENT IN BUYING DIVISION

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tracts, a new complexity element can be added to the system, or the standard hours for an old complexity element can be changed to reflect the new developments. If a manager knows of future workload changes, such as major shifts from initial provisioning to replenishment spares buying, he/she can transfer the manning requirements from areas with decreasing activity to those with increasing activity by adjusting the affected correlation factors.

Management can also make direct additives to this system if a peculiar situation is not covered by any existing standard. For instance, when the manpower management system itself was developed, an additive was allowed for one person to manage the day-to-day operations of the system on a full-time basis. Of course, all such changes to the E841 must be coordinated through both the AFLC Deputy Chiefs of Staff for Procurement and for Personnel before implementation.

A final advantage of E841 is that it provides descriptive workload information at all organizational levels to aid management in its many personnel decisions. For example, E841 can provide data that will allow a comparison to be made between the complexity of tasks in an organization, and the skill levels of the people actually accomplishing the tasks. This information is useful in determining whether one organization is effectively employing its personnel in comparison to similar organizations. The conclusion is that whatever management perceives as its particular uniqueness, the E841 provides a way of considering this uniqueness in determining procurement manpower requirements, and in determining the efficiency of assigned procurement resources.

A discussion of the disadvantages of the new E841 system primarily centers on the resource expense in forecasting requirements. The old manpower determining system employed a formula that required only the input of several variables - dollars, line items, and actions - before manpower needs could be forecasted. These values were retrieved from allied computer systems and did not require any significant procurement involvement. Forecasting manpower under the E841 system, however, requires the direct participation of procurement personnel to input and interpret workload data and to maintain the accuracy and reliability of the system. In addition to resource expense, criticism of E841 has been directed towards its self-adjustment feature for manpower efficiency which, some claim, tends to restrict innovation. As labor efficiency increases, the E841 system proportionately reduces future requirements based on the premise that it should take less people to accomplish the forecasted workload. Thus, any innovativeness that results in increased output will also result in decreased manpower. However, this criticism is inherent in any system that recognizes efficiency because it is a simple fact that an efficient work force can output more work than an inefficient one. The job of providing labor incentives rests with management and is not really a valid criteria by which the success or failure of a manpower management system can be judged. Notwithstanding these disadvantages, the positive aspects of E841 experienced during FY 76 and FY 77 far outweighed the negative.

UTILIZATION

During Fiscal Year 1976, E841 faced its initial practical application, and was, therefore, first subjected to the scrutiny of manpower and personnel specialists and the parochial interests of other organizations as they competed for limited manpower authorizations. During these manpower computations, E841 redefined procurement requirements for the five central procurement activities by identifying some 70 excess manpower authorizations. This refinement was due to E841's tight correlation between manpower and the volume and complexity of procurement's forecasted workload. The fact that these reductions were offered without the dictates of the AFLC Deputy Chief of Staff for Personnel, who recommends the allocation of all manning authorizations, gave weight to the credibility of the system at its inception. Since then, the E841 computations have demonstrated objectiveness by not only decreasing requirements but also adding them when procurement's on-board strength did not equate to its projected workload.

During FY 78, the five ALC central procurement directorates will be manned at approximately 92% of their projected requirements. Although this is less than full manning, the reduction was predicated on a fair share of the FY 78 President's budget cut which was spread among all organizations. Even with these reductions, procurement will enjoy manning at a higher percentage of its requirements than the other major logistics organizations within AFLC.

Another indication of E841's effectiveness is the 102.2% command-wide efficiency measurement for the central procurement buying organizations during FY 77. This is to say that the AFLC buyers are earning very close to those hours anticipated under the detailed time standards. Efficiencies significantly under 100% would have shown that the contract standards were undercutting the hours that were really required to award contracts, while efficiencies significantly above 100% would have shown that the standards were overshooting requirements. Because the standards appeared to accurately reflect the workload experienced during FY 77, the conclusion was drawn that the E841 system provided a firm foundation from which to build FY 78 and later procurement manpower needs.

PRODUCTIVITY INTERFACE

In addition to using E841 to forecast procurement manpower requirements and to manage manpower at the Air Logistics Centers, the potential exists for its use in productivity measurement. Productivity, in this context, is the ratio between organizational output and input during a particular period.

The concept of measuring procurement productivity is not new. For example, in 1974, an Air Force Academy study of USAF procurement productivity (USAFA-TR-74-9) used completed contract instruments as organizational output and assigned personnel as input. Because of its similarity to the initial attempts by AFLC to measure procurement productivity in 1975, the Academy study is used as a point of reference for addressing the possible adaptability of E841 to future productivity measurement.

The Academy's productivity measurement went beyond simply dividing total contract instruments by total assigned personnel. The study recommended that the contract instrument output be subjectively weighted by the following five complication factors (all tied to the DD 350): kind of procurement, contract placement, the extent of competition, certified cost or pricing data, and type of contract. Several weaknesses are apparent in using this approach to compute AFLC procurement productivity. First, the productivity measure includes overly simplified complication factors to describe the differences in procurement complexity from contract to contract. Second, it subjectively weights the complication factors to determine the magnitude of complexity of overall output and third, it treats all purchases under $10,000 (which represent 90% of AFLC's central procurement contracts) as being basically identical. The E841 data base may offer an opportunity to eliminate these weaknesses. First, the detailed E841 work standards - both by type instrument and by complexity element - offer an objective way of evaluating output. That is, output by the type of contract written could be weighted objectively by the respective earned complexity hours rather than a subjective complexity rating. Second, the 55 complexity elements would enable a much more accurate assessment of the actual contracting difficulties than the five general categories used in the Academy study. Finally, the E841 data includes detailed complexity measurement for all procurements, not just those over $10,000, so the output measure would be much more comprehensive under E841 than the Academy study.

Although E841 appears to be able to improve the methods employed in the Air Force Academy effort, it may also introduce its own peculiar deficiencies into procurement productivity measurement. The unresolved issues that would require analysis and decisions before a modification to the current E841 system was warranted include: What new errors would be introduced into the productivity analysis? What levels of organization would be affected by the measurement process? What costs would be involved in the data processing systems? To whom would the productivity measurement

be of value?

SUMMARY

E841 has enjoyed considerable success and has earned the confidence of both procurement specialists and manpower analysts alike. It has met its original goals and has provided procurement managers with a unique tool that is highly responsive to the fluctuations in workload volume and complexity, and to procurement policy changes as well. More importantly, it provides an accurate and current answer to the question of how many people does it take to accomplish the central procurement tasks within AFLC. However, beyond all these attainments, E841 looms as a pioneer effort into quantifying manpower management in support activities that are not hardware output oriented. It is this achievement that has the magnetic appeal to draw other staff or support organizations into similar systems. With Government's ever watchful eye on personnel expenditures, the E841 system may provide a significant insight into organizational effectiveness and efficiency and thus could eventually prove more valuable than first anticipated.

PURCHASING PERFORMANCE: MEASUREMENT AND CONTROL

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OVERVIEW

More than two hundred managers and buyers from eighteen leading private/public organizations were interviewed and more than two hundred purchasing performance measures were identified in this survey. Thirteen categories were established for the purchasing performance measures: (1) price effectiveness, (2) cost savings, (3) workload, (4) administration and control, (5) efficiency, (6) vendor quality and delivery, (7) material flow control, (8) regulatory/societal/environmental, (9) procurement planning and research, (10) competition, (11) inventory, (12) transportation, and (13) purchasing procedure audits.

Important differences were found in how the participating organizations measured performance in each of these key areas. Uses/benefits, inadequacies/limitations, negative/dysfunctional behaviors, and improvements associated with the measures are discussed. Statistical analyses of the research data revealed significant differences in the perceived usefulness and validity of various purchasing measures within and among the participating organizations.

PURCHASING PERFORMANCE: MEASUREMENT AND CONTROL

INTRODUCTION

The purpose of this research was to determine the state of the art in measurement of purchasing performance at leading private and public (federal level) organizations and to develop information which could lead to improved purchasing performance measurement and control systems. The research identified the measures in use in these organizations and obtained user ratings of the measures. In addition, users identified the uses/benefits, performance standards, inadequacies/limitations, and negative/dysfunctional behaviors for the measures. They also identified ways in which the measures might be improved. Statistical analyses of the quantitative rating data revealed differences in user evaluations of the measures.

RESEARCH SAMPLE

Eighteen organizations were surveyed and 248 interviews were conducted with managers and buyers. Approximately 60 percent of the respondents were managers and 40 percent were nonmanagers. All were experienced purchasing personnel and had considerable knowledge about the purchasing measurement systems used by their organizations. Firms from the automotive, aerospace, appliance, computer, chemical and electronics industries were included in the survey as well as five public organizations at the federal level. Purchasing managers at all levels of the organization were interviewed.

DATA COLLECTION

Four questionnaires were used to collect quantitative and qualitative data about the organizations, the purchasing department, the purchasing measurement systems in use, and user perceptions of the measures. Questionnaire I obtained data about the organization, including products sold; products purchased; numbers of people in the organization and in purchasing; the purchasing measurement system; and who received what measures, how often, and in what form.

Questionnaire II was used to collect data about the respondents' purchasing responsibilities and environment, and about the purchasing measures he/she used. Questionnaires III and IV were used to collect detailed data about the purchasing measures used by the respondent. Respondents were asked to rate each measure along thirteen dimensions. The dimensions were: (1) accuracy; (2) timeliness; (3) validity; (4) understandability; (5) comparability from reporting period to reporting period; (6) year to year comparability; (7) comparability between groups such as buyers, products, suppliers, and so forth; (8) frequency of use; (9) importance; (10) usefulness; (11) familiarity of users with performance standards; (12) challenge of the performance standards; and (13) degree of realism of the performance standards.

PURCHASING PERFORMANCE MEASURES

More than 200 purchasing performance measures were found in the organizations visited. These were grouped into 13 categories by the researchers, and a discussion of each follows:

<u>Price effectiveness</u>

Price effectiveness measures were used to measure: (1) actual purchasing price performance against plan; (2) actual purchasing price performance against market; and (3) actual purchasing price performance between buying groups/locations. Purchase price variances from plan were calculated on an individual line item and on a total purchasing budget basis. The indicators were the price variances measured in terms of: (1) actual unit cost minus planned cost; (2) a price variance

percentage, actual unit cost over planned cost; or (3) an extended price variance, actual unit cost minus planned cost multiplied by an estimated annual quantity (or quantity for the remainder of the planning period).

The key element in measuring price effectiveness against plan was the manner in which the plan was established. The planning process generally began with establishment of purchase requirements and line item purchase price forecast for the next budget period, usually a year. In some cases, forecasts were also made for comparison purposes by a cost accounting and/or industrial engineering group independent of purchasing. These forecasts were reviewed by purchasing and nonpurchasing management, such as finance and manufacturing. After management review and acceptance/revision, the purchase price plan was incorporated into the operating plan.

Price effectiveness was measured and reported, usually monthly, by comparing actual purchase price to planned price at one or more of four possible control levels. Level 1 was at the purchasing department level and included the overall material budget. Level 2 was at the major purchase product group and Level 3 was at the major final product sold. Level 4, which was the most detailed level, was at the purchased item level. The results at Level 4 could be aggregated up to Level 2 and Level 3, while results at Level 2 and Level 3 could be aggregated up to Level 1. The results at Levels 2, 3, and 4 could be reported by vendor, buyer, groups, and department.

Maximum control was exercised in those organizations measuring performance at all four levels. All organizations were at least measuring at Level 1. Effective control would appear to require measurement at least at Levels 1 and 4. Planning appeared most effective on an annual basis with revision allowable up to one month prior to the planning period.

Other indicators of price effectiveness were comparison of actual purchase costs to market and comparison of purchase costs at multiple buying locations. Organizations developed indices of actual purchases based on invoices paid and compared these to similar purchased items included in the Wholesale Price Index or the Wholesale Price Index in total.

Cost savings

Cost savings measures included indicators of both cost reduction and cost avoidance. Cost reduction required that the new unit cost be lower than the old unit cost on a line-item basis. Cost avoidance was more loosely defined and could be obtained, for example, by buying at a price lower than the average price being quoted, even though the new unit price would be an increase over the old price.

Cost reduction/avoidance was measured on the basis of an absolute unit or an annual cost reduction/avoidance, or by comparing actual cost reduction/avoidance to a budgeted or targeted cost reduction/avoidance. Cost savings data was usually collected and reported on a monthly basis by buyer, section, and department.

Selected uses/benefits of these measures included attention on cost reduction, discipline, provision of information on how to achieve cost savings, monitoring of performance to goals, comparability of cost savings, exposure to other functions, and performance appraisal. Selected inadequacies/limitations included different cost savings rules for different groups in the purchasing department or at different locations, use of credit only for negotiating price decreases and not engineering changes, subjectivity and lack of credibility of the measure, lack of cost savings reduction with price increases, lack of savings reduction with cancellation of a part, incorrect usage estimates, time required for reporting, difficulty in setting targets, and impact of external business conditions.

Analysis of the respondent perceptions of the cost savings measures revealed that the measures with the highest ratings were narrowly defined actual cost reductions. Furthermore, cost measures were rated higher in those organizations which provided the opportunity to adjust the quantity purchased and net out the true cost reduction.

Workload

All of the research sites measures workload in the purchasing department. This was broken down into three categories: (1) workload-in: a measure of the new work coming into the purchasing department; (2) workload-current: a measure of the backlog of work; (3) workload-completed: a measure of the work accomplished. Measures of the workload-in classification were usually counts of work received, including purchase requisitions received, purchase information requests received, number of protests received (government organizations), and number of pricing requests received. These counts were reported on a weekly, monthly, and year-to-date basis. Workload-in measures were reviewed regularly by purchasing management and were used to help predict and explain changes in other departmental measures. For example, an increase in workload-in could lead to a corresponding increase in purchasing's administrative lead-time if workforce size and efficiency stayed the same.

Measures of the workload-current category were, typically, counts of the backlog of work in the purchasing department. The two most

common counts were: (1) purchase requisitions on hand and (2) line items on hand. Another approach to measuring workload-current was to convert the workload into number of days of work at a standard rate. All of the measures were usually reported on a monthly basis along with the previous year's experience.

Measures found in the workload-completed category included purchase orders placed, line items placed, dollars placed, contracts written and price proposals written. In the public sector organizations, the workload-completed measures were subdivided into more specific categories, such as large purchases and small purchases.

Administration and control

These measures were used to help plan the annual administrative budget for the purchasing function and help control administrative expenses during the budget period.

The major question in this area of performance was how large the purchasing administrative budget should be. The crux of the question really is: What should our headcount be? Since salaries are the major item in the budget, most organizations felt that the answer to this question rested on the workload required of purchasing. This led to further problems in defining workload and establishing relationships between workload and headcount.

The most common method for establishing a budget was to start with the current budget and adjust it up or down, depending on the business forecast. The adjustment reflected management views on both the projected purchasing workload and the projected profit margins, based on economic conditions. For the firms using this approach, no formal methods were used to relate workload or business conditions to budget or headcount level. The budget was justified each year using whatever arguments were currently valid.

Another approach was to use a control ratio. In this approach, purchasing's administrative budget was established as a percentage (ratio) of another measure chosen to reflect the purchasing workload. Typically, the workload measure was planned dollar expenditure for direct material. Purchasing's administrative budget was calculated by multiplying the direct material input budget by the control ratio. The ratio was based on historical levels and was negotiated yearly between purchasing and higher management.

The material input budget was based on a projection of material input needed to support deliveries for the next year. The implicit assumption was that the purchasing workload was proportional to direct material input dollars. Once the ratio and the budget had been set for the year, a monthly ratio of actual administrative expenses to direct material input became a control figure for actual expenses.

A critical problem with the control ratio approach, using direct material input, was that much of the actual work of purchasing was completed before the direct material was received and paid for by the organization. Significant variations in purchasing workload and direct material input over time led to cycles of over- and under-funding for the purchasing department.

Several organizations were using or experimenting with methods for translating projected purchasing workload into a specific headcount number. There were several variations, but the essence was to establish a standard of workload per buyer, based on historical performance standards and/or time studies. Projected workload was then divided by the standard to calculate the total number of buyers required. The projected number of buyers needed might be multiplied by another ratio to get the number of secretarial/clerical employees needed. Finally, a fixed number of managers and other staff members would be added to get a total headcount for the department.

The critical number in this method was the workload standard. Typically, these standards were based on historical performance and the judgment of buyers and managers. The standards varied, depending on the difficulty of the items to be purchased. For example, a maintenance, repair and operating supplies buyer would be expected to handle many more part numbers than a buyer of high reliability parts.

A different approach was to set the standards in terms of hours per document and to establish how much time a buyer spent in buying activity each week. This time was then translated into a standard number of documents per year per buyer. A specific number of buyers was then established, based on the level of workload anticipated.

The most detailed and complex approach to budgetting was found in a public sector organization in the U.S. Department of Defense. Variations existed in the different Defense agencies, but all operated by establishing time standards for all activities within purchasing. Using these detailed time standards amd a workload forecast, the necessary workforce could be calculated.

The major difficulty in establishing an administrative budget for purchasing was deciding on an appropriate headcount level and a corresponding level of salary and benefit dollars. After reviewing the several methods, it appears that the most useful is between the

control ratio approach and the detailed time-standards approach. It appears reasonable to use aggregate standards, such as line items per buyer, to help establish the necessary staffing levels. The control ratio is often out of phase with the actual purchasing work-load. Detailed time standards do not appear to yield results that are sufficiently superior in most purchasing departments to justify their development and use.

Efficiency

Efficiency measures related purchasing outputs, such as line items placed, to purchasing inputs such as buyers. These measures ranged from two-factor measures that had one input and one output, to multifactor measures that related several outputs to several inputs.

Two-factor measures were calculated by dividing a count of some output from the purchasing department by a count of a resource input. A wide variety of inputs and outputs were counted by the organizations, with most using several different measures.

Among the more common two-factor measures were the following: purchase orders per buyer, line items per buyer, dollars committed per buyer, change notices per buyer, contracts written per buyer, average open order commitment, worker hours per line items, worker hours per purchase order, worker hours per contract, administrative dollars per purchase order, administrative dollars per contract, and administrative dollars per purchase dollar.

Purchasing administrative lead time (PALT) is a different kind of efficiency measure used by both public and private organizations. PALT is generally defined as the elapsed time from arrival of the purchasing requisition at the purchasing department to placing of the requisition with a vendor. Average PALT was usually tracked over time with an emphasis on keeping it below some standard time. Also, the requisitions with the longest elapsed time in the department were routinely identified and monitored until they were finally placed.

All of the other multifactor efficiency ratios were measures of labor efficiency found in the U.S. Department of Defense organizations. These measures were all essentially of the form: performance efficiency = earned hours divided by actual hours. Earned hours were calculated by multiplying the number of transactions completed by the standard time for completing the transactions. Actual hours were hours on the job minus the hours allowed for such items as sick leave, training time, and so forth.

Standard hours for activities had been established over the years by special teams working with the managers and buyers at each location. All the traditional methods of establishing time standards, including time and motion studies, work sampling, methods-time measurement, statistical analysis, historical performance, and judgment have been used. Much effort has been expended establishing and revising the standards and maintaining a data base on them.

In one public sector organization which had much higher user rating of their efficiency measures than the other public organization, it appeared that the difference could be accounted for by the difference in perceptions concerning the adequacy of the time standards in each of the organizations. The highest rated organization had the most detailed time standards. Furthermore, the newness of this system may have accounted for some of the differences in the ratings.

Vendor quality and delivery

Both vendor quality and delivery measures were found in use. Characteristics such as dollars by vendors were also measured. The vendor quality measures were: number and percentage of units/shipments/dollars of purchased items accepted/rejected; quality cost index = (total value of purchased items plus costs caused by vendor quality problems) divided by total value of purchased items; quality rating system based on number of quality problems; and quality index = (number of lots rejected divided by number of lots received) multiplied by (severity of the quality problem).

Vendor delivery measures were based on a number of pieces, shipments or dollars that were early, on time, or late. The critical element in these measures was the establishment of the scheduled due date against which performance was measured. Three basic approaches were used in establishing the due date: promised delivery date; need date to make user schedule; and due date based on requisition date, plus purchase time, plus vendor lead time, plus transit time.

It appeared that the most effective vendor quality and delivery measurement systems were those which provided detailed breakdowns by buyers and parts and provided the ability to measure vendor delivery against more than one need date. Furthermore, systems which appeared to be effective assigned causes to the types of delivery or quality problems.

Material flow control

Most of the organizations had reports and measures concerned with the flow of material from vendors to the buying organization. These reports can be classified into four functions: (1) identification of all open purchase orders and their due dates; (2) identification of past-due open orders; (3)

identification of material or orders that are needed immediately by manufacturing, that is, a hot list; and (4) measurement of how well purchasing buyers and vendors are doing in meeting due dates.

In many of the organizations, functions (1) and (2) were combined in the same reports. For example, a buyer might get a weekly listing of all open purchase orders, with overdue orders as a percentage of the total orders. The hot list in an organization was a separate report generated by manufacturing. Items would appear on the hot list when manufacturing was ready to assemble a project and discovered a shortage in the parts inventory.

The most sophisticated material flow control reports showed projected manufacturing requirements by part number by time period (usually weekly or monthly). The promised delivery time was shown in the same report. As manufacturing requirements and vendor delivery dates were updated, the report would reflect these changes.

It appeared that the most effective systems were time-phased material flow reports which showed both requirements and promised shipments over an extended horizon. This approach allowed buyers and expeditors to have a look into the future and alleviate problems before they became shortages in manufacturing. Also, it allowed a more systematic approach to expediting materials, allowing buyers more time to concentrate on buying.

Regulatory/societal/environmental

These measures provided information about purchasing's achievement of regulatory/societal/environmental goals. Examples included: (1) purchase dollars and percentage of purchase dollars placed with small and minority business; (2) purchase dollars and percentage of purchase dollars placed in labor surplus areas; and (3) number and percentage of minority employees in purchasing.

Procurement planning and research

Various indicators were categorized into the broadly defined area of procurement planning and research. The measures were generally used to monitor the amount of planning and research activity and its accuracy. These measures included the number of procurement plans established per year (including availability and price forecasting), price forecasting accuracy (actual to forecast), lead-time forecasting accuracy (actual to forecast), and number of make-buy studies completed. Each of these indicators was relatively straightforward from a measurement standpoint.

Competition

These measures provided information about the extent to which the buying organization was developing competition in the supply marketplace and improving purchase prices and terms. Measures included annual purchase dollars and percentage of annual purchases on national, area, or annual contracts and with sole source suppliers, competitive awards percentage, and formal advertised awards percentage.

Inventory

Inventory measures were found in several of the purchasing departments visited. These organizations typically measured turnover, tracked consignments, and projected inventory levels. Most respondents did not receive and use these measures because inventory management was not their responsibility. Therefore, only limited data was obtained about these measures.

Transportation

Transportation measures were found in three purchasing organizations. They were used to determine how much was being spent on premium transportation to obtain needed materials or products.

Purchasing procedure audits

These indicators provided data about whether purchasing procedures were being followed in establishing and monitoring contracts with suppliers. Audit procedures varied between organizations and included many categories of procedural violations. Audits were conducted by both purchasing and nonpurchasing personnel.

KEY PURCHASING MEASURES

Several measures used to control purchasing performance appeared to be key indicators at the organizations visited. These measures were price effectiveness, workload, cost savings, administration and control, vendor quality and delivery, and material flow control.

The researchers consider these to be key measures because they were extensively used and the respondents considered them to be most useful and important. Managing price, the administrative budget, workload, assuring continuity of supply, and managing vendors effectively were perceived as key purchasing objectives, and purchasing measures were developed and used to manage in these activity areas. Furthermore, even though some of the cost savings measures were suspect, cost reduction was viewed as a primary objective of purchasing needing measurement.

The above should not be interpreted to mean that the other purchasing measures found were unimportant or unnecessary, which is not the

case. All of the purchasing measures discussed were used to better manage purchasing performance.

STATISTICAL RESULTS

The objectives of the statistical analysis were to look for systematic variations in the respondent ratings and to find variables that could help explain the variation. Some of the major findings are discussed below.

The measure category with the highest mean rating over all respondents was price effectiveness. Competition and administration and control were next highest rated, ignoring measure categories with an insufficient number of ratings. These categories were rated high apparently because they were well defined measures that could be easily understood and accepted by purchasing personnel. They measured activities that are the core of the purchasing department, that is, purchase price and administrative expense.

The lowest rated category was cost savings, preceded b efficiency. The low rating of cost savings wa apparently due to the loose way in which cost savings were defined in many organizations. Cost savings figures were often thought to be easy to manipulate and were viewed skeptically both within and outside purchasing. In the few organizations with tight, narrowly defined cost savings measures, the ratings were higher. Low ratings for efficiency measures were due to the low marks given by the public sector personnel to labor efficiency measures.

Another significant finding was that the respondents rated all measures low on their use for "group-to-group (individual-to-individual and so forth) comparisons" and for "year-to-year comparisons." This finding was supported by many of the respondents, who stated that they did not like to be compared with other individuals or groups. They did realize the need for managers to evaluate them as part of the management process, but did not like for the comparisons to be made public on a regular basis. Furthermore, they felt that many of the measures used for comparison (for example, dollars saved) could not be taken at face value but had to be considered in light of the kind of items purchased by each individual.

The analysis also showed that organizations differed significantly in their overall ratings of the measure categories. The reasons are not entirely clear. The public organizations (with one exception) rated their measures lowest. The firms with the highest ratings were metal-parts fabrication and assembly operations. In general, the private firms rated their measures higher than did the public.

Significant differences also were found in the ratings of managers and nonmanagers. On questions concerning the objective characteristics of the measures (for example, accuracy and timeliness) managers and nonmanagers did not differ in their ratings. However, on questions concerned with uses of the measures (for example, comparisons, usefulness, importance) the managers rated the measures significantly higher than did the nonmanagers. One possible explanation was that the managers had developed the measures and thus had a greater commitment to their use.

GENERAL CONCLUSIONS ABOUT PURCHASING MEASUREMENT

The researchers developed some general perceptions of purchasing measurement as practiced at the organizations visited. These perceptions are not based strictly upon the hard data collected, but are synthesized from the total experience. We believe that these conclusions are as important as the findings reported earlier. They can be classified into systems-oriented and people-oriented attributes of purchasing measurement systems.

From a systems-oriented perspective, purchasing measurement is not free. There is considerable cost; the development and use of specific measures and their benefits must be weighted against the cost of developing and maintaining the system. In addition, a few measures well understood and narrowly defined are better than a large number of loosely defined, partially understood measures.

Effective measurement systems require a good data base which is consistent and valid and which all people in the purchasing organization use. The data base and the measurement system itself must be reviewed periodically so that unimportant measures can be weeded out and new measures added.

Furthermore, there is no one best way to measure. Each organization must conduct a detailed analysis of its own situation to determine which indicators are needed and will be most effective in its environment, and what the appropriate standards should be. The reporting requirements vary by levels in the organization and from organization to organization.

Lastly, one overall productivity measure in purchasing is probably neither feasible nor desirable. Multidimensionality of the purchasing problem, the masking effect of overall productivity measures, and the need to separate the components of such a measure to determine the cause of changes all mitigate against one overall measure.

Overall perceptions which focus on the people aspect of measurement include the belief that the measurement system is not a substitute for good management. However, good managers will have and use a good measurement system. Further, communication is important in developing effective systems. The goals, the measurement, and the evaluation process must be thoroughly understood by all in the organization.

Effective use of purchasing measures requires that they be used to positively manage the organization and not be perceived as mechanisms used only to punish people.

REFERENCE

This material is based upon research supported by the National Science Foundation under Grant No. APR75-20557. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

DESIGNING THE SPATIAL ENVIRONMENT TO EFFECT WORKGROUP INTERACTION AND IMPROVEMENT OF BUSINESS OPERATIONS

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INTRODUCTION

An important area of interest for the organization designer is the physical design of the work environment and how it influences behavior within the organization. Systematic attention to this factor is a relatively new area of interest for organization research. Physical environment is considered usually of marginal concern. The manager typically judges that it is unimportant to evaluate the way in which the physical setting impacts on behavior. However, the limited research that has been done reveals physical space has an important influence on the kinds of experiences and relationships people are having. The following example illustrates this point: [10:5].

When several executives in a large corporation decided that they wanted to work directly on some of their process problems, they hired a behavioral science consultant to work with them. After a diagnostic period, one of the major issues identified was hostility between two units of the organization. To deal with this, an off-site session at a conference center was attended by most members of the group. They identified problems, causes, perceptual differences, and possible solutions. They agreed to work on them over time.

When they returned to work some contact between groups occurred, but it died down quickly, and relationships returned to their pre-session state. One reason was a lack of resolution of fundamental areas of mistrust at the off-site session. Another was that the two groups were located on different floors of a high-rise office building, so they had little informal contact. The distance separating them resulted in few contacts; the motivation to continue to get to know and value the other group's members waned in competition with more immediate day-to-day contacts. The physical system as well as the social system of the organization must be considered if changes in the organization are desired. People are typically blind to the impact of the physical environment on their day-to-day lives, especially their work lives.

Several approaches in organization design deal with spatial factors but disregard behavioral implications. Location analysts consider costs, ease of performing basic tasks, availability of personnel and congruence between location and the organization's identity. In many instances location decisions are made on cost considerations alone, with behavioral implications carrying little weight [10:16].

Another approach to spatial design is office landscape (Burolandschaft) from Germany [9] [3]. The aim of this approach is specifically workflow oriented. The proponents of this approach design "landscapes" with paths and areas after extensive studies of the flows and contacts of the system at work. This approach mirrors what the organization is, whereas organization designers are working to bring the system to what it should be with physical changes being facilitators of this development.

Limited systematic research on the impact of physical settings on organizational behavior has identified several aspects of the physical environment. Osmond [5] refers to those factors that discourage interaction and stable relationships as sociofugal in character. Such factors as spatial physical barriers, noise, bright lighting, and extreme temperatures are sociofugal. Conversely, sociopetal arrangements support and encourage development of interaction and stable interpersonal relationships. Osmond describes spatial context in terms of location, distance, and semi-fixed or fixed features.

A study of a college dormitory reveals some of the sociofugal-sociopetal qualities of a nine story complex [12]. Each floor was sociopetal in character since the residents were physically divided from other floors so each floor developed into a cohesive social group. Richards and Dobyns [7] identified the way in which changes in physical arrangements in an office affect intragroup and intergroup relations. A small group of employees in a bank was initially located in a small enclosed work area with its own entrance from the outside of the building. The group of workers developed a high degree of cohesion, a well structured social system, a sense of special status and of working in a friendly atmosphere.

In a reorganization the group was moved to another floor to a similar room except that the boundary was defined by steel mesh and there was no separate entrance. This arrangement allowed the group to be directly supervised and observed from outside the steel mesh. Increased stress, less satisfaction, more absenteeism, passive resistance to instructions, a greater degree of overt opposition and decline in efficiency developed in the unit Those behavior patterns could be attributed to the type of supervision and elimination of special status, but these, in

turn, were made possible by the removal of the barriers. The few existing research studies support the importance of studying organization design characteristics as important determinants of behavior in organizations.

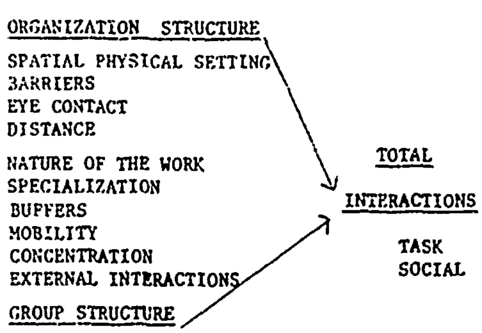
THE STUDY

An empirical study of six organizations explored the importance of spatial physical arrangements for determining work group interactions. Several structural dimensions of organizations as well as some characteristics of group structure were included in the study to control for other possible determinants of interactions. Structural dimensions of the organization consisted of the spatial physical environment and the nature of the work. Spatial physical environment is defined in terms of distance, degree of eye contact and the extent of physical barriers between individuals in the work group. Characteristics of the nature of the work considered were the degree of specialization, existance of buffers, mobility, intensity of work and degree of external interactions required by the job. Group structural factors were age, sex, race, friendship and supervisory status.

The importance of spatial arrangements, nature of work, and group structural factors for determining work group interactions were assessed. The frequency of face-to-face interactions between individuals were measured at the point of initiation. The frequencies were subdivided into task or social related interactions.

The following model describes the causal relationships:

FIGURE 1
INTERACTION MODEL



THE SAMPLE

The sample consisted of six different organizations. Three organizations were involved in manufacturing and three were service organizations. Samples of small work groups were obtained within each of these organizations. The tasks represented in the study were mostly of a clerical and service nature. Eight hundred and sixty interactions in all were recorded.

Data was collected by observation, questionnaire and self-recording forms. Demographic factors and factors concerning the nature of the work were obtained by questionnaire from each individual. Spatial physical setting variables were collected by observing types and numbers of barriers and by measuring distance. Interactions were tabulated on self-recording forms.

FINDINGS

Table 1 shows the results of the step-wise regression using task interactions as the dependent variable. Seven of the variables were significant at t .05. Friendship was the most important variable with a beta weight of .22. Spatial physical barriers was the second most important variable. Three of the seven significant variables were from organizational structure and four were from group structure.

TABLE 1

Task Interactions Regressed on Organization and Group Structure

Variable	t-test of b	Beta Weight
Friendship	6.07*	0.22
Barriers	3.69*	0.21
Supervisory Status	5.04*	0.19
Race	2.64*	0.09
Sex	2.04*	0.08
External Interactions	2.07*	-0.07
Mobility	1.86*	-0.07
Age	1.46	0.05
Distance	.82	0.04
Specialization	1.16	0.04
Buffers	.49	0.02
Concentration	.31	0.01

*p<.05

Table 2 shows the results of the step-wise regression using social interactions as the dependent variable. Eleven variables were significant. Spatial physical barriers explained the most variance with a beta weight

of .25. Friendship followed closely with a beta weight of .21. Again barriers was found to be a significant variable for explaining interactions.

TABLE 2

Social Interactions Regressed on Organization and Group Structure

Variable	t-test of b	Beta Weight
Barriers	4.26*	0.25
Friendship	6.13*	0.20
Mobility	3.92*	-0.13
Eye Contact	2.85*	0.12
Age	3.43*	-0.12
External Interactions	3.39*	-0.11
Sex	2.79*	0.11
Race	3.42*	0.11
Concentration	3.10*	0.11
Buffers	2.49*	-0.08
Supervisory Status	2.09*	-0.07
Specialization	1.54	-0.05
Distance	.15	-0.01

*p<.05

In the last step total interactions (task plus social) was analyzed using the set of independent variables. The results of the regression appear in Table 3.

TABLE 3

Total Interactions Regressed on Organization and Group Structure

Variable	t-test of b	Beta Weight
Barriers	4.60*	0.27
Friendship	7.35*	0.25
Sex	2.87*	0.12
Race	3.55*	0.12
Mobility	3.22*	-0.11
External Interactions	3.11*	-0.11
Age	3.77*	-0.10
Supervisory Status	2.58*	0.09
Concentration	1.81*	0.06
Eye Contact	1.40	0.06
Distance	0.65	0.03
Buffers	0.90	0.03

*p<.05

Again barriers and friendship have the highest beta weights with specialization not significant at the required level. Nine of the independent variables were significant at t .05.

The correlation matrix presented in Table 4 indicates the relationships among six variables where (intercorrelations were .40 or greater).

TABLE 4

Correlation Matrix of Variables with Highest Intercorrelations

	Barr.	Dist.	Cont.	Frnd.	Supr. Stat.	Sex
Barriers	1.00	0.77	-0.66	0.39	-0.06	-0.23
Distance		1.00	-0.45	0.40	0.11	0.06
Eye Contact			1.00	-0.32	0.22	0.32
Friendship				1.00	0.03	0.01
Supervisor Status					1.00	0.52
Sex						1.00

Barriers is highly correlated with distance and eye contact. Sex and supervisory status are also moderately correlated. Sex, distance and eye contact do not play significant roles in the explanation of variance probably due to the multicollinearity which exists between them and other variables in the regression. The multicolinnearity between barriers, distance and eye contact results in an unstable b value for barriers. This is reflected in the t values presented in Tables 1-3 where barriers has a high beta weight but not the highest t value.

DISCUSSION AND CONCLUSION

The results of the study indicate that as spatial barriers increased both the frequency and types of interaction were adversely affected. As the type of barriers changed from separation by different floors to separation by a short distance, the frequency of both types of interactions increased. Barriers was the most important variable for explaining variance for total interactions. These findings are consistent with the results of Van Der Ryn and Silverstein's study of the dorm complex. The only barriers investigated by their study was separation by floors. However, when a fuller range of variables is introduced this basic hypothesis is supported.

The findings also support Osmond's theories about the sociopetal characteristics of barriers. Osmond tested his theories in psychiatric institutions, airports and bars but the results are verified in this study for work environments and for on-going groups rather than chance groupings which often occur in airports and bars.

Richards and Dobyns' results are further amplified by the results of this study by taking work environments and measuring actual interactions between the members of the group. While the Richards and Dobyns' studies highlighted the importance of spatial barriers for the development of group cohesion, their study lacked quantative measures of group interaction.

This study highlights the importance of the spatial setting in organizational design. The industry application can be generalized to the program office procedures of the procurement environment. Operations of the program office can be improved by increasing both social and task interactions. Results of industry studies indicate that both types of interactions can be increased by more effective spatial design.

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MULTI-NATIONAL ACQUISITION ISSUES

COST ISSUES IN COMPETITIVE INTERNATIONAL SOURCE SELECTIONS FOR MAJOR HARDWARE

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ABSTRACT

Driven by North Atlantic Treaty Organization (NATO) standardization and designs which provided for interchangeable and interoperatability, near term hardware acquisitions may well be procured from competing manufacturers in a truly international type competition. While policy is evolving to provide top level guidance to control such activities, a review of current source selection practices and procedures identifies selected issues associated with international competition which are worthy of addressing. These issues deal with a variety of subjects, but this paper addresses only the select, but important, cost issues. This paper first identifies a manageable set of important cost issues and then proceeds to detail solutions to the problems raised by the issues themselves.

From a combination of experience and recently gathered research data, this presentation examines the cost presentation, estimating, evaluation, negotiation, and reviewing issues associated with the procurement of a major international piece of Department of Defense hardware. Included is a look at the proposal and its peculiar needs when it is directed to both domestic and foreign producers. Emphasis is on the type of documentation and data that would be necessary for use in evaluating competing proposals, giving full considerations to the very different approaches and quality in data of both friendly nations and the United States military producers. If international competition is to be truly international without an absolute veto power or final determination on the part of the United States, then the Source Selection Team for the evaluation and recommendations would be international in makeup. The evaluation itself proposes problems of placing competing proposals in a comparative position when different currencies and rates of inflation exist. Interchangeability and interoperatability directly involves operating and support costs. Parts, which may be interoperatable and interchangeable, are not designed with the same reliability. In evaluating competing, friendly nations' proposals and the United States producers' proposals, on-site validation of contractor data and claims proposes shear geographic handling of such validations. The audit agencies on-site and the lack of audit agencies on-site is an example of a problem area. With the evaluation completed, negotiations to clarify with the proposing contractors, cost technical, and other terms and conditions, requires a reexamination of our own professional training and its limitations in an effort to develop flexibility in our evaluation and formats which is so vitally necessary to reach a final source determination. Extending beyond the evaluation and negotiation, the professionalism must be soundly based in order to assure firm and fair rationale and methodology which can provide to the unsuccessful offeror the basis for the selection, which avoids any international claim of "fouls." Finally, the review and approval cycle when tailored to international competition with friendly nations is examined to see what pitfalls exist. The review and approval mechanics can be so structured to accommodate the interests of the friendly nations, as well as our own acquisition agency.

The research behind this paper has included contacts with various Project/Program Managers, who have been involved in major end item procurements with an international flavor. While their lessons learned are directly associated with evolutionary stages of international competition, we can extrapolate from this data to develop the issues identified in the early paragraphs of this paper. This extrapolation, when analyzed, presents a set of preferred solutions based on the writer's personal experiences in three major source selections. This paper fills an apparent research void in the detailed planning for methodology, rationale, budgets, and manpower requirements associated with true international competition.

THE APPLICATION OF COST ACCOUNTING STANDARDS TO FOREIGN CONTRACTS

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INTRODUCTION

The Cost Accounting Standards (CAS) Board was established in 1970 by Public Law 91-379. The Board was set up in the legislative branch of the government as an agent of the Congress with the function of promulgating "...cost accounting standards designed to achieve uniformity and consistency in the cost accounting practices followed by defense contractors." (1) To date, the Board has issued fifteen standards and has published six proposed standards that are currently out for public review and comment.

The standards are basically applicable to all negotiated defense contracts in excess of \$100,000. Negotiated contracts which are priced on the basis of catalog or market price and prices set by law or regulation are excluded. Certain other categories of contracts are also exempt from CAS requirements. These include: contracts awarded to small business; contracts awarded to Canadian Commercial Corporation; contracts awarded to United Kingdom contractors; certain contracts under \$500,000; contracts both executed and performed outside the United States; and contracts awarded to a business unit of other than a small business concern where that business unit has less than \$10 million of CAS covered contracts and CAS covered contracts account for less than ten percent of the business unit's sales. (2)

Public Law 91-379, as implemented by CAS Board regulations, has always been interpreted to require that the CAS clause be included in contracts and subcontracts negotiated with foreign contractors unless they are otherwise exempt. Since the inception of CAS, the Department of Defense (DOD) has experienced difficulties in obtaining CAS acceptance and compliance from foreign governments and contractors. While the exemptions for contracts awarded to the Canadian Commercial Corporation and United Kingdom contractors have helped streamline the contracting process with firms in those countries, contractors in other countries are required to comply with CAS to the same degree as contractors in this country. The implementation of all the CAS Board standards, rules, and regulations in these foreign countries requires a great amount of effort by both U.S. and foreign personnel. Because collaborative programs involving foreign contractors are expected to increase in the future, there is much concern about the practicability and necessity of expending such a large amount of effort to implement CAS on each foreign contract. (3)

There are a number of issues which arise when implementing CAS on foreign contracts. The most important are sovereignty, conflicting national laws or regulations, administration, lack of a legal/regulatory framework, and benefit. The author's experience with these issues in recent DOD efforts to implement CAS overseas has led him to conclude that requiring full CAS compliance is not appropriate for foreign contracts. This paper discusses the issues, briefly looks at the present approach of full CAS implementation, and suggests two alternatives that would facilitate the contracting process.

THE ISSUES

The first issue to be discussed is national sovereignty. Foreign contracts are performed by foreign contractors, in foreign countries. The governments of these countries, and their contractors, are often opposed to the imposition of U.S. laws and regulations on their contracts. They maintain that the United States has no sovereignty, and therefore no legal right to impose these requirements on such contracts. This argument has been put forth most strongly on cooperative effort programs where the United States and foreign governments are jointly funding a program and the United States is acting as an agent or partner. The foreign governments have suggested that if every nation participating in a collaborative program were to insist on imposing their own laws and regulations on each other, an agreement would never be reached. With the increased interest in collaboration on major programs, this issue has become even more significant.

A second issue has to do with the laws and regulations of foreign countries. Foreign contractors are required to comply with the procurement, accounting, and tax [illegible] and regulations of their respective nati[illegible] Their normal business and accounting practices are cast within the framework of these laws and regulations. To date it has generally been U.S. policy to superimpose cost accounting standards on foreign contractors to the extent that their own national laws or regulations do not prohibit them from complying with CAS. This approach tends to ignore the practical question of compatibility. It is one thing to say that foreign laws do not prohibit the application of a CAS Board standard or requirement, and yet

(1) 4 CFR 301.2
(2) 4 CFR 331.30 & ASPR 3-1204.1

(3) For the purpose of this paper, a foreign contract is any contract or subcontract with a foreign contractor or government.

another to say that CAS is compatible with foreign laws, regulations and business practices, or that CAS will, in fact, be effectively implemented.

The third area for consideration is CAS implementation and administration. Many of the standards are quite sophisticated. U.S. government and U.S. industry personnel have frequently disagreed with each other, and among themselves, on exactly what was intended by a particular CAS requirement. In spite of these disagreements, cost accounting standards have been successfully implemented in some locations in the United States. But, this successful implementation has been due primarily to close, timely face-to-face cooperation between U.S. government and U.S. contractor personnel--personnel who are knowledgeable with respect to cost accounting standards and the contracting process. This type of cooperation is frequently hindered on foreign contracts. First, there are language differences to overcome, and perhaps more significantly, the circumstances surrounding the contract or subcontract. Many recent foreign contracts and subcontracts are the result of international cooperative programs. When the United States enters into these programs, foreign governments may insist as a condition of the program that their national auditors perform audits on their own contractors, permitting United States personnel to observe only. While these agreements may permit U.S. auditors to conduct an audit in extraordinary circumstances, they nonetheless, limit visibility of U.S. contract administration and audit personnel. Foreign government and industry personnel cannot be expected to be as knowledgeable or highly motivated about implementing a United States law as are their counterparts in the U.S. While there is, as yet, little experience in this area, it appears that it may prove impracticable to impose cost accounting standards in situations where overall program and political considerations limit the ability to implement and administer CAS.

The fourth issue embraces elements of the three preceeding areas and is a causal factor in their existence. This issue deals with the basic framework in which CAS is implemented and administered. In the United States the Congress passed a law establishing a Board to promulgate cost accounting standards. The Department of Defense implemented this law in its contracting regulations. By law and regulation, defense contractors in the U.S. are required to comply with these standards on all applicable defense contracts and also flow down CAS requirements to subcontracts. Contracting agencies have an established legal/regulatory framework, and the leverage that it provides, to support their implementation/administration efforts for domestic contracts. The situation is somewhat different for the foreign contract. The U.S. contracting agent, be it the government issuing a foreign prime contract, or a prime contractor issuing a foreign subcontract, is required by U.S. law to flow down CAS if applicable. However, there are not, as yet, any laws in foreign countries which compel foreign contractors or governments to comply with Cost Accounting Standards Board rules and regulations, nor is there an established regulatory framework. CAS must be implemented by mutual agreement of the parties via a contract clause or memorandum of understanding. Where a foreign contractor or government unequivocally refuses CAS, the U.S. agent does not have the leverage of law to require compliance; neither does the U.S. agent have waiver authority. The desire for business, previous business relationships, or other factors are the only motivators left for effecting compliance with U.S. public law. Absent these motivators, a waiver must be sought. Thus, without an established legal and regulatory framework as a base, the U.S. contracting agent is in a perilously weak negotiating position to effect acceptance of CAS.

Finally, recent experience indicates that the implementation of CAS for foreign governments and contractors is administratively burdensome and costly. In the past three years, U.S. government personnel permanently assigned to the Washington, D.C. area have expended over 150 man-days of travel overseas solely to resolve CAS implementation and administration problems. This does not include time expended by these personnel on foreign problems while in the United States, nor does it consider time expended by U.S. government personnel permanently assigned overseas. Attendance at overseas CAS meetings by foreign government and contractor personnel and cognizant U.S. prime contractors indicates that they are also expending considerable cost and effort in trying to implement CAS.

CURRENT TRENDS

Foreign procurements are expected to increase substantially in the future due to increased emphasis on collaborative programs between the United States and its allies for major weapons systems. Public Law 94-361, as implemented by the Department of Defense, has resulted in the NATO Standardization/Interoperability program. This program reflects national policy and will likely stimulate increased foreign purchases. Economic trends are also encouraging more international collaboration for defense products. The trend in cost accounting standards is also upward. The CAS Board presently has six proposed standards out for comment and a list of projects waiting in the wings.

With the prospects of more foreign contracting ahead, the DOD must do all it can to facilitate the acquisition process while still providing adequate protection for U.S. taxpayer dollars. CAS, in spite of foreign resistance, has contributed to greater visibility of foreign

accounting practices. Attempts to impose CAS and other requirements have generated much discussion with U.S. allies overseas regarding their accounting practices. This does not imply that foreign governments have changed their laws, or that foreign contractors have improved their accounting practices as a result of CAS. However, the very problem itself has forced some beneficial communication between the parties. We may also assume that if CAS could be fully implemented overseas that we might ultimately enjoy better visibility of contract costs and more reliability in contractor cost estimates; two benefits we have experienced to some degree on domestic contracts. However, the controversies regarding full CAS implementation raise a question regarding both the method and desirability of the present full implementation policy.

THE CURRENT POLICY

The present policy of full CAS implementation has the potential advantages of greater cost visibility and more reliable contractor cost estimates. However, if it is the intent of Congress and the CAS Board that Public Law 91-379 be fully implemented overseas, then several basic changes must be made. First, the CAS Board, as the Congressional agent for CAS should be clearly charged with responsibility for introducing CAS to foreign governments; effecting foreign government acceptance; and assisting foreign governments in establishing the necessary CAS legal/regulatory framework. This should be accomplished <u>before</u> DOD or its contractors are required to <u>impose</u> CAS on a foreign government or contractor. These efforts should be coordinated with Department of State, Department of Defense, and other applicable U.S. government agencies. Clear understandings should be established between the U.S. government and foreign governments as to what standards will apply to foreign contracts as well as how they will be implemented and enforced. This is not offered as a casual suggestion. CAS was effectively implemented in the United States because first, a base was established in law and an agent was set up to implement the law. For CAS to be effectively implemented overseas, similar action is required for foreign governments. The present arrangement of contractually requiring full CAS implementation overseas without the legal/regulatory framework has placed U.S. contracting personnel in the position of "promulgating" CAS for foreign contractors and governments. U.S. contracting personnel should not be responsible for effecting such "promulgations," especially when there is no legal or regulatory basis for them to enforce compliance.

If full CAS implementation is, in fact, the U.S. Government's intention with respect to foreign contractors and governments, then the approach described above is the appropriate method of pursuing that implementation. However, the road to implementation will likely be a long one. It is this author's opinion that full compliance is neither realistic nor necessary in the international environment. A more reasonable, practicable approach is needed which provides a long-term policy and also deals with the immediate short-term problems. There are two options, short of full compliance, that could eliminate, or at least reduce, the current problems.

ALTERNATIVES

The first option is total exemption of CAS for all foreign contracts. This has several advantages: it effectively eliminates the controversies discussed earlier in this paper; it avoids the future problems we would encounter if we continue trying to impose CAS overseas; it eliminates the administrative costs and burdens of foreign CAS implementation and administration for the governments and contractors involved; and finally, it is easily implemented, requiring only one sentence in paragraph 331.30(b) of the CAS Board's regulations. The primary disadvantage to this approach is the possible lost potential for increased cost visibility and more reliable cost estimates.

The second option is the application of the CAS Board's Modified Contract Coverage to foreign contracts. This would basically require foreign contractors to disclose their accounting practices under the same conditions as U.S. contractors and comply with two almost axiomatic accounting requirements. They would have to estimate, accumulate, and report costs consistently as required by CAS 401, and consistently allocate costs incurred for the same purpose as required by CAS 402. This approach has several appealing features: it acknowledges the primary purpose of the CAS legislation, accounting consistency; it establishes a base-line for all future foreign contracts and eliminates the problems associated with introducing new standards when they come out; it allows for differences in individual countries' accounting laws and practices; and finally, it is easily implemented since all the machinery already exists in Part 332 of the CAS Board regulations; it need only be made available to foreign contracts. This approach does have a major disadvantage. Many of the arguments against full CAS coverage, especially national sovereignty, are equally applicable to the Modified Contract Coverage. Thus it may provide only partial relief from the problems.

CONCLUSION

The ultimate goal of any acquisition, foreign or domestic, is to obtain the needed goods or services at fair and reasonable prices. In the international contracting [illegible], U.S. policies must protect U.S. interests but at the same time recognize the interests of

other countries. If every nation participating in a collaborative defense acquisition program were to insist on imposing all their applicable national laws and regulations, an agreement would never be reached. It is unreasonable and impracticable to insist that CAS be fully implemented on foreign contracts. This author believes that the requirement for full CAS implementation should be eliminated. U.S. interests can be adequately protected, and the problems attendant to foreign CAS implementation and administration eliminated or reduced, by implementing one of the two alternatives suggested. Total exemption would greatly facilitate the contracting process and business relations in the international environment. Modified Contract Coverage would provide partial relief, while recognizing the CAS law's basic consistency requirements. Either of these options are easily implemented. Experience indicates that attempts to impose requirements beyond these alternatives becomes significantly more difficult to explain, negotiate, administer and enforce.

A CONCEPT PAPER ON TOMORROW: ACQUISITION AND SUPPORT OF THE TOTAL FORCE

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PREFACE

This article is a by-product of a considerable amount of research conducted by personnel from the Air Force Acquisition Logistics Division (AFALD) into the field of International Logistics. Within the AFALD it had become apparent that recent trends in International Logistics were causing numerous new and unique management problems associated primarily with the acquisition and support of new systems. Accordingly, a study was directed to systematically identify exactly what was causing these problems, followed by recommended action for achieving near, mid, and long term solutions. The study team attempted to follow a scientific problem solving process, but as in many real world situations the most difficult task was in defining the problem. As the study progressed, however, it became apparent that many of the problems resulted from the fact that the Department of Defense, as well as civilian industry, lacked a comprehensive set of procedures for meeting these new trends.... making it extremely difficult to carry out some of our latest foreign policy commitments. This realization stimulated further research into US planning for the future, which in turn led to this paper on acquisition and support of the Total Force. Coincidentally, the results of this research are appropriate for the theme "Working Tomorrow's Contracting and Acquisition Systems Today". Indeed, the findings of the study indicate that if we are to achieve the security needs of the future, it is imperative that the Department of Defense, as well as the commercial sector, structure their planning around the concepts addressed in this paper. The following discussion is a summary of the key elements of this extremely complex and overwhelming concept which is being developed in substantial detail to be published this summer.

THE CONCEPT

Let us begin by defining exactly what is meant by the term "Total Force". Total Force is defined as the sum total of active and reserve components of the United States, those of our allies, and the additional military capability of our allies and friends made available through local efforts or through provisions of appropriate security assistance programs. The Total Force concept is expressed as a Department of Defense policy which recognizes all components contributing to the deterrence of war and protection of United States national security interests. The objective of this policy is to insure that an appropriate balance is achieved throughout all phases of planning, programming, manning, equipping, and employing the components of the Total Force, so that United States national security objectives can be most effectively and efficiently achieved (4:39).

Given the above definition and a clearly stated objective, the question then becomes: How does one insure that an appropriate balance is achieved throughout all phases of planning, programming, manning, equipping, and employing the respective components of the Total Force? The answer of course, is through international cooperation ... disciplined and resolute cooperation motivated by the very survival of the components. Although at this time there may be no "Master Plan" for acquiring and supporting systems on a fully cooperative basis, there are many indications that top level policy makers are moving in this direction. Key concepts such as "interoperability", "standardization", "codevelopment", "coproduction", and "cooperative logistics" are bringing the United States levels of magnitude closer to the other components of the force. President Carter's proposal to NATO in May in 1977 provided a vital stimulus to this concept when he called for improvements in coordinated national efforts, and emphasized the importance of improved cooperation in the development, production, and procurement of standardized alliance defense equipment. In response to this proposal, the defense ministers developed short and long term initiatives highlighting cooperative defense improvements. Without going into detail on the content of each initiative, let it suffice to say that each task addresses a deep concern within NATO ranging from the preparation of collective need statements to improved logistics support procedures. Closer to home, Secretary of Defense Brown recently issued a new DOD Directive 2016.6, Standardization and Interoperability of Weapon Systems and Equipment within the North Atlantic Treaty Organization (NATO), and has requested the services to examine and report on opportunities for more common R&D, greater interoperability and standardization, and for buying, licensing, or co-producing European as well as US equipment to create more of a two way street (2:5-[illegible]). [illegible] initiatives are certainly important but the Total Force Concept is not limited to NATO,

and this fact alone requires a significant expansion in thought.

What this all adds up to is that new trends are upon us, and comprehensive reforms are necessary in our acquisition and support procedures. The first step must be to establish a cooperative requirements process for identifying, evaluating, and prioritizing collective operational requirements to justify the initiation of major system acquisitions. This process should identify the area; project the threat; identify existing capabilities to meet the threat; identify deficiencies in that existing capability; identify constraints; assess the impact of not acquiring or maintaining that capability; and lastly, establish a plan for developing and acquiring systems to meet the proposed threat. Already we are seeing evidence that this is beginning to happen. Within the DOD we have seen significant changes in our requirements process which require us to consider existing sources outside the United States. On the other extreme, we also have procedures for developing systems specifically to meet foreign needs.

We are all familiar with foreign governments purchasing US goods and services to meet their defense requirements, but we have not frequently seen the opposite take place. If we are serious in our efforts to support the Total Force concept, we will all be seeing more of this as we continue to seek collective solutions to meet common needs.

The second major element in this overall system must be to develop a cooperative acquisition process for converting these needs into articles and services. This process should follow a logic similar to that of the US acquisition process consisting of well defined phases, separated by key decision points. This cooperative acquisition process should be tiered, consisting of sequential levels of cooperative involvement ranging from cooperative development, through various stages of licensing and cooperative production.

With some restrictions, practically every new tactical system being acquired by the US is subject to consideration for some degree of cooperative activity. Perhaps the most noted example is the multinational F-16 US/EPG Program. In fact, Secretary of the Air Force Stetson noted that many foreign governments view the outcome of this arrangement as a test of US sincerity,... and are looking to it as a demonstration of US willingness to cooperate (3:56). Numerous other examples of coproduction could be discussed, but unquestionably the precedent for cooperative acquisition has been set. Let us now proceed to discuss the third element of this overall system.

The last, and possibly most complex process, involves establishing and maintaining an effective cooperative logistics support base. To develop such a system would require extraordinary effort to plan, negotiate, and implement cooperative supply support procedures, cooperative maintenance plans, cooperative facilities plans, cooperative technical data management programs, cooperative transportation and handling plans, cooperative training programs, and an extensive management information system, to mention just a few. Specific examples within each of these area could be discussed at great length; however, let it suffice to say that the task of establishing an effective and truly cooperative logistics system is overwhelming.

Although the underlying theories expressed in this concept are not new, the overall concept is so complex that volumes could be written about the advantages, disadvantages, and potential implications of each element of the process. To be sure, this relatively simple concept is fraught with difficulties. To mention just a few would include the realities of group decision making; existing legal restrictions; fluctuations in currency; different funding processes; the release of proprietary information; the dissemination of technical information; delays in feasibility studies; differences in threat estimations; and the basic fear of losing jobs to foreign competitors (1:51-52; 2:11-12). Against these very real concerns we must weigh the advantages of international cooperation. In addition to obvious advantages in doctrine and operational employment a natural by-product of this process would be built in interoperability and standardization. There would certainly be economic benefits resulting from increased economic order quantities, and the multiplier effect could become extraordinarily effective.

Despite numerous disadvantages and advantages to this concept, the bottom line is that we really do not have any choice. The time is right to follow the administration's bold and innovative proposals and to establish procedures for collectively identifying, acquiring, and supporting common needs of the Total Force. To be sure, the intent of this proposal is not to proliferate the acquisition and sale of arms ... but rather to reduce inefficiency and the unnecessary use of resources which could be otherwise dedicated to achieving other national or international objectives.

SUMMARY

The theme of this paper can be summed up by stating ... as we look to the future we can no

longer afford the luxury of procuring and supporting hardward individually. We cannot afford to do it in the US Air Force, US Army, US Navy, or US Marines. We cannot even afford to do it across the US Department of Defense. We must look to how, when, where, by whom, and why new systems will be used and as we do so it becomes obvious that the answer lies in the Total Force policy. In much the same manner as we have seen an evolutionary shift from Grant Aid to Foreign Military Sales, we are now experiencing a new trend toward increasing international cooperation. Therefore, as we seek solutions to meet the needs of the future, we cannot fail to accept this very real concept on tomorrow.

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A HISTORY OF MULTINATIONAL COLLABORATION FOR DEFENSE PROCUREMENT WITHIN THE NORTH ATLANTIC ALLIANCE -- CONSTRAINTS AND POSSIBILITIES FOR THE FUTURE

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ABSTRACT

This is an analysis of the evolution of multinational collaboration for defense procurement amongst the 15 members of the North Atlantic Alliance, in order to provide historical depth and a broader perspective for present and future developments in this area. Particular attention will be given to the nature of the environment and the accumulation of experience in the organization and management of multinational consortia and licensing arrangements.

The roots of the problems facing Alliance collaboration in defense procurement research to the very core of the international political order--national sovereignty, and its manifestations in national defense and national economic policies. The tariff liberalization in Europe starting in the late '50s led to the need to develop non-tariff instruments of national policy (large national firms in either public or private ownership) in promoting national welfare and development and the necessity of concentrating national industries through mergers so as to better deal with the increased exposure to foreign competition. This has meant that the national state industry relationships have taken on an increasing particularism as they have moved toward more of a one-to-one correspondence, often resulting in structural rigidities that hinder transnational collaboration and the efficient reallocation of resources internationally (i.e., greater economic integration).

In Alliance armaments collaboration there must be compatibility of industry-to-industry, government-to-government, and industries-to-governments. Collaboration can be blocked by any one of the four (or more) parties' narrowly defined perception of self-interest in its internal or external markets or its national defense requirements. The defense procurement environment of each ally is unique and may limit or foreclose the leverage of the other governments and firms. Each part is thus faced with a higher than normal degree of risk and uncertainty due to greater exposure to the unilateral actions of any one of the foreign participants.

Therefore, with the U.S. aerospace/defense industry dominant in the world market generally, and its largest single market in particular (the U.S. market), it is natural that there is only limited interest in taking on the extra risks and loss of sales involved, simply in order to gain access to Europe's smaller, less penetrable markets. Although the Europeans need access to the U.S. market, they have less to offer in return, across the board. It is this unequal bargaining position, combined with the differences in priorities that makes transatlantic compatibility of the defense/aerospace industries so difficult. Even though there has been an important new factor introduced--the change in the U.S. policy toward NATO--this general situation will continue in the future, be it somewhat modified.

The pattern of the European F-104 replacement choices portrays roughly the constraints and the two dominant trends in Alliance armaments collaboration. First, however, if a nation can still go it alone through the sufficiency of the size of its own national market or by developing an extensive export market, as with France's Mirage series, it will. Only then if it can't, will it attempt to co-develop a system on a parity basis with one or two other allies (MRCA). Although this results in increased costs to a given system, it is both cheaper for each nation than unilateral development, while also supporting the national technology base. If the extra cost involved in co-development is not feasible, then the remaining option (short of purchasing the system) is licensed production of an ally's system so as to at least minimize disruptive BOP problems and maximize domestic employment (the F-16 consortium). The first choice of going it alone has been primarily a U.S. option (although the new U.S. policy changes this somewhat); however, also one that is sometimes open to the U.K. and France, and even occasionally the FRG and Italy. More often than not though, these European nations have increasingly had to resort to the co-development option, or in the case of the smaller nations and often FRG and Italy, licensed production or minor subcontracting role.

The general framework for NATO procurement reflects the constraints referred to above. On the intergovernmental level, although the North Atlantic Treaty Organization has been invested with juridical personality and the privileges necessary to perform its diplomatic tasks through the 1951 Ottawa Agreement, the member States have never shown any desire to delegate to any entity independent of themselves, the necessary authority to carry out the purpose of the treaty--defense, defense procurement, and logistics remain a national affair. This is the reason behind the failure of NATO's own internal weapons procurement procedures, through the NATO Basic Military Requirements (NBMR's, 1959-66), which led to the abolishment of NATO's Armaments Committee and the establishment of the Council of National Armaments Directors in 1966. This resulted from the recognition that all Alliance authority rested with the national governments, and if Alliance armaments

collaboration was to be promoted, it would have to be done on a more limited and realistic basis. "NATO has no permanent procurement role, no established procurement regulations, no generally applicable standards on which contractors can safely rely, and on which they can predict costs and perform forecasts."(1) Nevertheless, the Alliance does provide an ideological banner, a structure for the planning and coordination of the member states' armed forces, and as an information and coordination conduit, facilitating ad hoc government-to-government agreements for defense procurement.

"NATO" programs are the result of inter-governmental agreements covering two subcategories: (1) weapon projects consisting of any two or more member states; or (2) special infrastructure projects funded by all 13 DPC members. For the weapon systems, these inter-governmental groupings set up: either their own NATO-chartered NPLO's (NATO Production and Logistics Organizations) with a Board of Directors, consisting of representatives from each participating government, and an inter-governmental project Management Organization; or simply an international Steering Committee, involving no legal entity and relying on one of the participating nations to perform the procurement function.

In NATO infrastructure (involving Alliance-wide funding) ordinarily the government of the host nation (where the construction is taking place) carries out the procurement function under the supervision of NATO's standing Infrastructure Progress and Payments Committee. This involves several special procedures like NATO's International Competitive Bidding rules (can be waived by unanimous vote of the P&P Committee), audit of contractors by NATO's International Board of Auditors, and a Board of Arbitration for disputes. Although, in the exceptional cases of such larger, more complex projects as NADGE, NICS and most likely NATO/AEW&C (AWACS), the need for more centralized management has led to the creation of the international Management Organizations (NPLO's), even here there is still considerable reliance on the national procurement authorities. Therefore, the framework within which contracting takes place is provided by the national laws and regulations, and any relevant government-to-government agreements.

Where any two or more a ied governments are procuring the same basic system and a multinational industrial effort is involved, there are seven principal patterns that industry-to-industry relationships take within the Alliance. These patterns roughly represent the types of cooperation in R&D and production in which the Alliance members' firms have been involved, with variable degrees of success. Nevertheless, the experiences of learning by doing have provided these firms and their respective governments with invaluable insight into the complex set of problems faced. This has involved dealing with differing national policies, military requirements and doctrines, regulations, specifications and practices, as well as working with firms with differing capabilities, priorities, standards and practices in the organization and management of multigovernment/multifirm efforts. The seven patterns that will be elaborated on through case studies are: (1) A single European nation's firm(s) producing an American system under license (the simplest of the patterns), (2) Licensed production by multinational consortia of a U.S. system under license, (3) A U.S. firm as the licensee, which--unlike licensing the other way--also involves redevelopment (Americanization), (4) European multinational codevelopment and production (which has been the most significant of these patterns), (5) Transatlantic codevelopment (which has proven to be the most difficult of the patterns), (6) General offset procurement agreements for single nation purchases such as involved in the FRG purchase of the F-4, and (7) U.S. led multinational production consortia (involving no codevelopment) contracting with both U.S. and European governments in an ad hoc grouping, or the whole Alliance, and including the F-16 ACE-HIGH, NADGE, and NATO/AEW&C.

The present U.S. government policy has brought about the introduction of more diffuse Alliance considerations in equipment selection discussions. For the U.S. aerospace industry, this increases the need to better understand past arrangements and problems in Alliance collaboration, so as to be better able to hedge their positions in the U.S. market and to gain leverage in the European national markets by further developing their relationships with European governments and firms. And as for the DOD, although it has already gone a long way in the development and implementation of this new policy, it will mean that certain previous practices will still need to be modified so as to be in line with the present policy.

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REQUIREMENTS MANAGEMENT

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STRUCTURED ANALYSIS AND QUALITY ASSURANCE FOR SERVICE CONTRACTS

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INTRODUCTION

During the past several years, it has been the policy of the Federal Government to rely increasingly on the private sector to satisfy its needs for services. This well known policy is expressed in the Office of Management and Budget Circular A-76 and is fully supported by the Department of Defense and in turn, has been implemented by each of the military services. Service contracts in the Air Force, for example, amounted to over $1.3 billion in fiscal year 1976 alone. As a result of this trend toward contracting out, service contractors have assumed a major role in day-to-day operations of bases, posts, camps, and stations. Contractors provide diverse services such as transportation, refuse collection, food services and maintenance of sophisticated defense related equipment. Some contractors are responsible for an entire installation support function; for example, at Vance AFB Oklahoma, a contractor provides the full spectrum of support services.

The move to contract services precipitated numerous management problems. The Air Force Logistics Management Center (AFLMC) reviewed a large variety of statements of work and contract management schemes used by bases and found numerous weaknesses. The most apparent weakness was the ill definition of requirements and consequent inability to measure true performance. The AFLMC, with HQ USAF support, established an Air Force project to develop new streamlined procedures which would focus a contract manager's attention on key areas of a specific service contract. This paper describes, in general terms, the approach taken by the AFLMC in this project and briefly discusses the project's conclusions. The major recommendations include a method of identifying and stating service requirements so that a contract will accurately express the minimum essential requirements and their associated measurable characteristics, and a method for assuring that the contractor has provided the contractually required services.

THE CONCEPT OF QUALITY

Previous studies of service contracting have identified numerous factors which influence service quality. A list of major factors always includes the contractor, the statement of work, the government quality inspector and the quality inspection method. The performance of the contractor and the government quality inspector are direct functions of the statement of work and the quality inspection method. This relationship allowed the AFLMC to focus on the statement of work and inspection methods since they were most amenable to influence by centrally established policies and procedures. The rationale was that contractor performance can only be measured through specific requirements. Further, the ability of an inspector to determine whether a requirement has been met is a function of the quality assurance method as well as the measurability implicit in the requirement statement, e.g., a requirement "to keep a room cool" is subject to measurement error since cool is a very subjective word; however, a requirement "to keep a room's temperature between 68 and 72 degrees" can be quite precisely measured. At this point, the project scope was narrowed to zero in on (1) ways to write statements of work which include useful and measurable requirements, and (2) efficient and effective ways to determine whether the requirements are being satisfied.

THE APPROACH

Approaches to defining requirements have traditionally involved translating existing methods or processes into a statement of work, hence they were process oriented. Contractors were asked to provide satisfactory service using procedures dictated by the government. In looking for a better way to write a statement of work, the AFLMC decided to take an approach that would look at a performance, output oriented statement of work, rather than procedures. This approach to service contracting, while certainly not new in a conceptual sense, has not been widely reported on; therefore, the AFLMC found itself in the position of trying new applications for old theories. Field personnel were initially resistant to this concept since it is a traumatic experience for a functional manager to be asked to describe the service needed in discrete, measurable units. Functional managers underestimate their ability, thankfully, and our experience shows that they can define precise service requirements if they use a carefully structured analysis technique.

Systems analysis, when applied to a proposed service contract, partitions the desired service into sets of jobs which then serve as focal points for defining a measure of job performance. From a contractor's view, the service contract requires that the inputs - people, facilities, material, and the government statement of work, etc. - be integrated into a

production function (process) which produces the contractually required output services. The contractor uses quality control methods, as a control loop, to measure output services against requirements, identify out-of-tolerance situations, and take corrective action to bring the work process back into control if substandard services are produced.

This general view of a service contract permits the use of structured analysis to define the output services of the process and the standards associated with that output. An unambiguous definition of a job permits the measurement of output by both the contractor, from a process control viewpoint, and the government, from an acceptance of the service viewpoint.

OVERVIEW OF THE ANALYSIS METHOD

The development of a performance oriented statement of work and the techniques for quality assurance surveillance starts with structured analysis. Structured analysis provides the basis for writing a statement of work by assembling all the essential information descriptive of each element of service to be performed. The steps in the AFLMC approach to analysis are described below.

a. Organizational Analysis. The process of analysis starts at the macro level of organizational analysis. The existing in-house operation is examined to see how it is organized to accomplish its job and data is gathered which describes and measures, in a general way, the services currently performed. Vehicle maintenance or inventory management are examples of the way in which services are initially described.

b. Job Definition. Organizational analysis provides macro level statements of service output, however, these statements are vague and cannot be measured. These macro level services do provide excellent guides to critical service requirements which can be broken into their constituent elements by defining the work processes that make up the macro level service. For example, the major process of inventory management has as constituent elements such work processes as stock ordering, warehousing, stock issuance, and stock accounting. Each of these work elements can be broken into smaller elements of service. Job definition is complete when the total service need is broken into discrete jobs, where each job can be unambiguously defined and possess the potential for measurement.

c. Job Analysis. Job analysis is conducted to clearly define exact job outputs. This activity includes a thorough analysis of each job's inputs, process, and output factors. This very critical step is complete when each job has been described in terms of the action which starts the job, what happens to the inputs during the work process, and what measurable job output is created by the work process.

d. Job Classification. The classification step is a decision point which requires management to decide whether it wants a contractor to provide a service or retain the function in-house. This decision point is used to reduce contract cost growth which frequently occurs as managers find new jobs which they want added to a basic contract. Classification makes these additions a conscious decision.

e. Data Gathering. Workload data is collected for each job classified as a contract job and government furnished resources are clearly stated. Contractors need this information in order to prepare a responsive and realistic bid. This information also becomes an essential part of the government's quality assurance plan as described later.

f. Performance Analysis. The job analysis step produced statements which described measurable outputs which are associated with each job. This step converts those outputs into performance values which include the desired response together with a range of acceptable values around the desired response. Emphasis is placed on stating the desired response in terms which permit objective measurement. The technique forces the statement of work writer to state what standard is associated with an element of service, how the service can be measured, and what allowable error rate or acceptable quality level can be present before a service becomes unsatisfactory.

g. Governing Directive Analysis. Historically, service contracts have included a statement of work which tries to replicate the in-house operation which it is to replace. Promiscuous imposition of military functional procedures creates an environment in which the service contractor is inhibited from devising cost effective approaches which provide the desired service. During this analysis the functional manager requesting the service contract is forced to catalogue all directives that pertain to the service, which are used for in-house operations. These directives are then examined to determine if they are absolutely required to satisfy one or more measures of job performance. This step is designed to ensure that a directive will not be included in the statement of work unless an absolute need is proven.

h. Deduct Analysis. Service [illegible] in-variably fail to provide one or more elements of service and the government must avoid paying for services that have not been rendered in a satisfactory manner. This is in addition to other contractual remedies such as [illegible] default. Deduct analysis starts with [illegible]

specific job outputs discovered during job analysis, their frequency of performance, and resource input. The analyst then derives the percentage of cost contribution which each job makes to the total contract effort. When a service is not performed within an acceptable quality level, the government is now in a position to make appropriate monetary deductions from normal contract payments for specific non-performance. These deduction percentages along with the performance values are placed in the statement of work and become a part of the contract which is awarded after bidding.

The structured analytic steps bring a macro statement of requirements down to micro level, measurable outputs. Each of these outputs is described in terms of the performance characteristics that are critical if the objectives of the service contract are to be met. Knowing the exact deliverables in the contract permits the definition and construction of a quality assurance program that will assure that delivered services meet requirements prior to their acceptance.

SERVICE CONTRACT QUALITY ASSURANCE

A major difficulty in service contracting stems from imprecise statements of work and inadequate methods of contract surveillance. The preceding part of this report described in general terms a technique for making a statement of work more precise. This part of the report describes the quality assurance technique developed by the AFLMC for base level service contracts. The approach has been extensively tested with existing service contracts and the system is now being implemented throughout the Air Force. The key document that implements the concept is a surveillance plan. This choice of nomenclature serves to distinguish it from the traditional checklist method of contract surveillance since a surveillance plan as designed by the AFLMC is an organized, planned approach to quality assurance.

Quality control models are generally broken down into acceptance sampling and process control approaches where each model would use sampling by attributes or variables as appropriate. Acceptance models aid the purchaser of a product or service in determining whether the product or service satisfies minimum standards. This model description fits the government's needs exactly since a major objective of this entire approach is to determine whether services satisfy specific requirements. A contractor, however, is concerned about the work process itself and therefore would logically establish a quality control scheme using process control techniques. This approach focuses the government's attention on acceptance of services and allows the contractor to establish process control procedures which should reduce the numerous complaints of service contractors who claim the government meddles too much in trying to dictate process methods. Attribute sampling has been used most widely in applying this approach to acceptance sampling, however, variable sampling can be easily incorporated if it is appropriate. Attribute sampling satisfies most of the needs for monitoring service performance since it can be applied to either job standards which can be precisely measured, e.g., temperature of wash water in a kitchen; or to job standards which are more subjective, e.g., food taste. In addition, Military Standard 105-D, "Sampling Procedures and Tables for Inspection by Attributes," is an excellent reference for developing service contract surveillance plans. This is particularly true since the structured analysis technique permits clear definition of output services, demands the statement of standards, and forces decisions about acceptable quality levels. In other words, the vague expression "service" was refined through the steps described earlier into discrete service elements called jobs, where each job had associated with it a set of measurable performance characteristics. These performance characteristics collectively are used to determine whether a job has been satisfactorily performed. Attribute sampling when applied at the service acceptance decision point allows a government contract monitor to efficiently and effectively evaluate performance by answering yes or no to simple statements about the performance characteristics.

The major product contained in a surveillance plan is the sampling guide. The sampling guide brings together the MIL-STD-105D sampling plan, information on how to draw a random sample to select those output services to be checked, and an inspection procedure for checking the output. Once constructed, this document contains all the information that an inspector needs to do the job when random sampling is the method chosen to check the service output. The major components of the sampling guide are explained below.

a. Acceptable Quality Level. MIL-STD-105D describes the acceptable quality level as the maximum percent defective which for a service contract is translated to mean the frequency with which a service can be performed unsatisfactorily and still not cause total rejection of that service. Many functional managers initially find this bothersome since they want everything 100% correct all the time. Most functional managers eventually realize that there are only two ways to get such service: (1) by paying an exorbitant fee, or (2) by setting a low level of quality. This statement of acceptable quality level is an excellent feature of this overall approach to service contracting, since it forces the functional manager to make conscious decisions and tradeoffs between service quality and cost. The

data developed during performance value analysis is the source of acceptable quality levels for the sampling guide.

b. Lot Size. Lot size is an estimate of the total volume of jobs for a particular type job and time period. For example, the number of meals served in a dining hall during a month could serve as the lot size for sampling purposes. As noted during the analysis discussion, the technique calls for data gathering about workload by specific service output. This workload or frequency data is the source of the lot size.

c. Sample Size. MIL-STD-105D is used to obtain the proper sample size based on lot size and other statistical criterion. For example, if the lot size were 185 jobs, the month's sample would be 32 jobs using Inspection Level II and the single sampling plans for normal inspections contained in MIL-STD-105D.

d. Sample Procedures. Single sampling schemes have been used most widely in current contracts developed under this approach; however, other sample plans can be adopted without loss of generality. The sample procedure requires that each service job within a lot be uniquely identified which can be accomplished by systematically inspecting every i'th job, by assigning job numbers to every service job, or other plans which preserve the random nature of the sample. Random number tables are provided for use in those situations where jobs have unique numbers.

e. Inspection Procedure. Attribute inspection requires the statement of definitive criteria which is used to determine whether or not a service meets a standard. These criteria, developed during the performance analysis step, now become guidelines used to determine whether a specific job has been satisfactorily performed. The standards along with a written procedure for the inspector's use in checking the service become the inspection procedure.

f. Performance Criteria. MIL-STD-105D describes specific acceptance and rejection numbers based on sample size and acceptable quality level. As inspection progresses, a simple tally of the sample observations of service output enables the inspector to determine if a lot or group of services is of acceptable quality by comparing the number of defects discovered with the acceptance and rejection numbers.

g. Problem Location. Service contracts call for many interfaces with on-base government agencies. Frequently, factors associated with these interfaces can cause a contractor to provide unacceptable service. For example, if the statement of work required the contractor to use the government supply system for repair parts, a low equipment in-commission rate could only be chargeable to the contractor if the government supply system were not a source of parts delay. Problem location is not a direct part of the sampling guide. However, it is part of the surveillance plan and is necessary before any decision can be made to accept or reject the lot of service outputs.

CONCLUSION

This paper has described the approach taken by the AFLMC to resolve many of the historical problems associated with base level service contracts. In particular, it addresses a method to insure acceptable service, whose major components are a definitive statement of work and a quality assurance technique. Structured analysis, with its step by step procedures has been described as a means of defining specific service outputs and their associated standards. A quality assurance surveillance plan, based on MIL-STD-105D techniques, has been proposed as the method to perform acceptance sampling of the service output. Analysis and the surveillance plan, when taken together, answer persistant questions on how to succinctly state requirements and measure progress toward satisfaction of these requirements.

LIFE CYCLE
MANAGEMENT OF THE EMBEDDED COMPUTER SYSTEMS
SOFTWARE ACQUISITION PROCESS

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ABSTRACT

This paper explains the process of acquiring Embedded Computer Systems (ECS) within the context of the Department of Defense life cycle acquisition phases. The major objective of the paper is to provide a description of the ECS acquisition process in its current state. The acquisition tasks and hardware/software interrelationships are described during each of the phases of: concept formulation, validation, full scale development, production and deployment. The paper is intended to cover the acquisition process from a conceputal point of view by focusing on the interdependence of hardware and software development.

INTRODUCTION

Today, almost all major Department of Defense (DOD) weapon systems such as the Trident Submarine or the F-15 Air superiority Fighter are critically dependent on the proper operation of Embedded Computer Systems. A key component of these electrical-mechanical systems has become the computer and its integrated software.

An Embedded Computer System as used within the DOD is a system which is dedicated to a specific function within a larger system whose primary function is not data processing. There are two key characteristics of Embedded Computer Systems, which distinguish them quite well from other computer systems. In an Embedded Computer System the hardware and software are designed and developed simultaneously. In non-embedded (general purpose) computer systems the hardware is developed to be compatible with a multitude of programming purposes. The embedded computer and its software are developed as an integral part of the much larger electrical-mechanical system. Another characteristic of note is that the embedded systems are mobile. That is, they are within a moving system with all the implications of miniaturization, cooling and power requirements. (5)

One of the most perplexing and urgent problems now facing the DOD is how to control the mushrooming costs of the software needed to operate Embedded Computer Systems. The DOD now spends billions of dollars annually on software. These costs are projected to continue to rise in the forseeable future. In some recent major programs the cost of embedded computer software has been three times the cost of its accompanying hardware. It has been estimated that DOD annually spends from 3 to 3.5 billion dollars on the various forms of software. Approximately 55% to [illegible]% of these dollars can be classified as weapons systems (embedded) software costs. (1)

The spiraling use of embedded computers in major weapons systems has not been accompanied by appropriate management techniques, tailored to the unique environment of acquiring embedded computer software. This lack of management response based on a clear understanding of the acquisition process within both DOD and industry may be the reason for the escalating cost of software within the DOD. This article provides a descriptive model of the ECS acquisition process in furtherence of understanding. The focus is to introduce the concept of an interdependent system for hardware and software development for Embedded Computer Systems.

THE EMBEDDED COMPUTER SYSTEM MODEL

TRADITIONAL LIFE CYCLE PHASES

Department of Defense Weapons systems generally go through five phases during their life. The phases in sequence are: Concept Formulation, Program Validation, Full Scale Development, Production and Deployment.

Before a new system can be seriously considered for acquisition some change in the environment must occur. The military threat may change or technological advances may be made that allow significant increases in military capabilities. Existing systems may be aging or deteriorating. Many different changes may occur in the environment simultaneously, but the key is that there must be a felt need before a new system can be conceptualized.

DESCRIPTION OF THE MODEL

Concept Formulation. During the Concept Formulation Phase the emphasis is on whether or not the felt need can or should be established as a firm requirement.

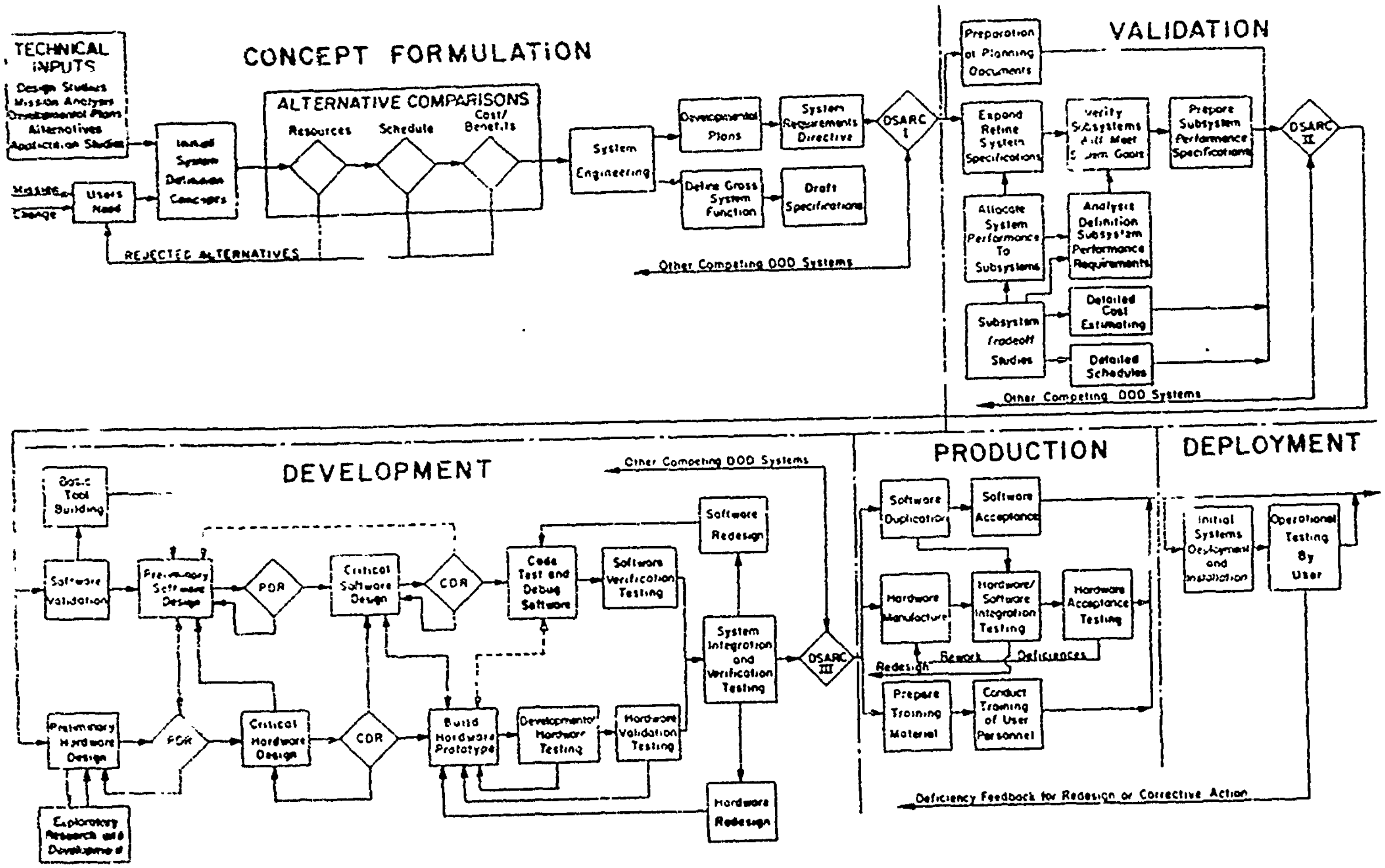

Figure Detailed Activities of Embedded Computer Systems Acquisition

Various studies are performed to determine if the envisioned systems are technically/economically feasible and if it can be produced in time to realize the desired benefits. Concept Formulation can be considered both a defining and a weeding out process. The major output of this phase is a description of a system which will fulfill the operational needs of the user. A key attribute of this phase is the minimal expenditure of funds.

As shown in the Figure, a system (project or program) must pass a series of hurdles prior to completing the concept formulation process. These hurdles are designed to optimize the alternative approaches to the problem solution. The primary emphasis of this phase is on the major weapons system (aircraft, missile, ship, etc). The subsystems (such as embedded computers) are considered from a functional viewpoint. Only if the major system passes the hurdles of concept formulation is it appropriate to expend funds to determine how to achieve the subsystem's performance.

Validation. The Validation Phase was formerly called the contract definition phase or project definition phase. During this phase only the minimum preliminary design and engineering necessary to define the system's performance is accomplished. An analysis and evaluation is accomplished to determine the technical and economic adequacy of the proposed system requirements. The completeness, effectiveness, and any deficiencies in the proposed system are evaluated in light of the users' mission. This analysis and evaluation process results in a refinement of the original performance concepts, systems definition and performance requirements.

After the major system has been treated, each subsystem (e.g. avionics, airframe, propulsion, etc) is analyzed, evaluated and defined in detail. The results of this subsystem activity is an operating concept, performance requirements and a set of design requirements. These concepts and requirements are then compiled into specification documents which will govern all of the following development activities.

In parallel with the technical refining activities are the detailed planning, cost estimating and scheduling activities. Plans are made for the design, development, test, integration and eventual acceptance of each major subsystem as well as the overall system. Detailed cost estimates are accomplished and preliminary schedules are established. The work of this phase is usually a joint effort between the government and a civilian contractor (or contractors), at least for major weapons systems. After design work accomplished during the concept formulation phase is verified; the major technical approaches are validated through extensive analysis and possibly even some hardware development. The last part of this phase results in a contract definition to be implemented during the Full Scale Development (FSD) Phase.

Most authors who explain the acquisition of software (including embedded computer software) do two things. First, they ignore the hardware or only make passing references; second, they start the Concept Formulation Phase with the analysis of software requirements and carry this analysis through the Validation Phase. The Development Phase then starts with coding, testing, debugging, and parallel design efforts. Although the above sequences may be desirable, instances of this sequence happening are very few and far between.

Some analysis of software does occur during the Concept Formulation and Validation Phases; but compared to the detailed studies, analyses and even exploratory development of hardware; software studies, are so minimal as to be almost non-existent. Software is studied and analyzed only enough to establish two facts. First, the system can and should be controlled to some degree by software; second, approximate software sizing activities are accomplished to give a rough order of magnitude of the job and software costs.

Boehm in his often quoted article referred to the software as secondary to hardware. His emphasis, however, was that software decisions and requirements should not wait until after the critical hardware decisions are made, but should be accomplished first. These facts lead us to the conclusion that the hardware and software activities during the Validation and the Development phases are in reality significantly offset as shown in the Figure.

Full Scale Development. Because of the timing of software validation we now break the Full Scale Development (FSD) Phase into four separate parts. In this phase of the acquisition cycle, we will cover hardware development, software validation (analysis), software development and testing.

Hardware Development. The hardware phase of FSD covers all the work necessary to build one or more prototypes for testing. The development of hardware can be generally broken down into the stages listed below:

1. Preliminary Analysis and Design.
2. Critical Analysis and Design.
3. Building of Prototypes.
4. Developmental Testing.
5. Verification Testing.
6. Validation Testing.

During the preliminary design the developer and buyer gain an increased confidence in the feasibility, cost and performance of the system through a critical look at the system concepts. This phase does not normally result in drawings for fabrication. Major modules and their interfaces are defined. Functional flow diagrams are prepared. General layout drawings may be prepared. Brassboarding and testing of critical components may occur. Maintainability and reliability requirements are addressed. Preliminary plans for further development, test, manufacture, installation, integration and support are developed. The results of the preliminary design review are inputs to the next stage, which is the critical design.

In the critical design stage the recommendations of the preliminary design review are implemented. The work in this stage is the detailing of design and analysis necessary to build the prototype. Detailed drawings for fabrication and part selections are made. Basic packaging decisions are made. If the basic processor has not already been selected in the preliminary design phase, it will be selected here. Building of prototypes although listed separately, occurs during the critical design process. Developmental testing also starts during this phase. Often a number of preproduction prototypes will be fabricated to allow various activities to occur simultaneously. For example, because of the delay (or offset) in the beginning of software activities, the design, coding and implementation of the software may occur simultaneously with reliability, environmental and other developmental testing of the hardware.

The end of the critical design stage will be a critical design review. The detailed design is generally completed at this point. Because validation/verification and integration testing require the integration of the software into the total system they will be covered after the software development.

Software Validation. The software analysis starts with the input of the overall performance specifications for the embedded computer system. An analysis is performed in conjunction with the preliminary design of the hardware to determine the software/hardware interactions required to supply the system performance functions. From these interactions the software operating and design concepts are completed and documented in a software performance and design specification.

Software Development. The actual software development can be broken down into five stages.

1. Basic Tool Building.

2. Preliminary Design.

3. Critical Design.

4. Code and Debugging.

5. Developmental Testing.

The basic tool building stage is used to build such support tools as compilers, environmental simulators, documentation aids, test case generators, test data, management systems, assemblers, system exercisers, standards enforcers, special computer consoles or other necessary tools. (6)

During the preliminary design stage, analysis and tradeoffs are performed to determine alternative approaches to the computer programming problem. The design approach is selected during this activity. The programming technique, such as top-down programming, ego-less programming or chief programmer team programming, is selected. Compatibility requirements are defined, such as interface definitions, timing, message formats and available computer memory. Other activities are:

1. Definition of Inputs/Outputs.

2. Designation of Programming Tasks.

3. Data Base Description.

4. Functional Flows are Created.

5. Allocation of Storage.

6. Costs and Schedules are Updated.

7. Development of Initial Test Plans.

At the end of the preliminary design a formal preliminary design review is held to determine if the software development is ready to continue to the critical design stage.

During the critical design stage activities which are necessary prior to actual coding of the software are accomplished. The individual and system program flows are finalized. Preliminary test plans and procedures are finalized and submitted for approval. A major result of the critical (detail) design process is the compilation of the major portions of data necessary to describe the computer software product. This data will become the proposed product specification at the end of the validation verification process.

The critical design review is [illegible] to insure the design is sufficiently mature to permit start of the actual coding. Also the testing procedures and plans are a major focus of this review.

During the coding stage the flow charts are converted to lines of coded instructions. The programming process is usually accomplished on a module or subroutine basis. The module or subroutine is then desk checked for illegal expressions, logic errors and deviations from programming standards. The subroutines or modules are then put through developmental testing with the special software tools such as simulators or special test cases. After sufficient modules have been checked out they are then compiled and assembled into a larger computer program segment which can then be tested and the process is repeated until the entire software program has been compiled and assembled and developmental testing performed. The computer program now is ready to enter the formal testing stages.

Thus far the principle outputs of the software development have been: (7)

1. Computer Program Development Specification
2. Test Plans and Procedures
3. Drawings
4. Flow Charts
5. Computer Input and Output Formats
6. Source Program Statement (Listings)
7. Object Program in Machine Language.

Testing. During the testing stage two types of tests are performed -- verification testing and validation testing. Verification testing is sometimes referred to as systems integration testing. During validation testing both the hardware and software are testing separately against their requirements as spelled out in the specifications. The object of this testing is to determine if the specified requirements will be met. After successfully completing the validation testing the software and hardware are combined together and subjected to verification testing which is essentially the application of input/output analysis to results obtained under a simulated operational environment.

The results are then used to determine the degree of satisfaction of the user's requirements.

The testing phase normally ends with an audit of all performance functions. This audit is used to document that the performance requirements have been met. Once the audit (Functional Configuration Audit) has been completed the system has been qualified for production. An audit is then performed to establish the product identification. This audit (Physical Configuration Audit) is used to verify that the technical documentation is complete and a true description of the product qualified.

Production. The Production Phase may cover the production of one item or of many items. In the case of a one of a kind item, the Production Phase is a continuation of the development process. In production of many items we have the traditional mass production line. The topics of acceptance and quality assurance become increasingly important.

In traditional procurement models, production is depicted as a block of time, after which operation and maintenance starts. Actually in a multiple item procurement operation and maintenance will start very shortly after the first production item rolls off the assembly line. The first item or items are deployed to the field and run through a shakedown process to certify that they are operationally ready. So we can see from the figure that there are parallel production, deployment and operational/maintenance phases. The relationship of these phases is described below.

During production separate and parallel activities are accomplished. The hardware items are sequentially manufactured over a long period of time. The hardware is sequentially accepted on a one-time basis. Activities necessary for the support of the hardware and software are accomplished. The software production activities amount to nothing more than duplication and acceptance of the software programs developed during the Full Scale Development phase. This duplication and acceptance can be accomplished in a matter of days.

During the software support stage two major activities can be expected to occur. First, the technical writing and editing is accomplished to complete the user maintenance and operation documents. The second activity is that of training the user's personnel to operate and maintain the system.

Training materials are prepared if they have not been previously developed during the Full Scale Development phase. The training program is then conducted. Training may be through briefing or formal classroom instructions. Two separate and distinct types of maintenance training must be provided for. The user's personnel must be trained to maintain the equipment and the software.

The last activity of the production phase is the acceptance of both the software and hardware. Previously during the development phase tests were designed and specified for acceptance. These tests are designed to demonstrate that the hardware and software comply with their production acceptance requirements. When the equipment and

software pass their acceptance test we have established with confidence that they will perform satisfactorily in their operational environment.

Deployment. Deployment activities take place in two different ways. First, in the normal sense each individual system must be deployed to the field before normal operations can start. The other deployment concept is that of initial system deployment. The initial system deployment activities are essentially a shakedown cruise. The system is taken to the field and installed. In the case of aircraft systems, the equipment is normally installed at the factory. Field installation activity for aircraft systems is generally concerned with the placement, check out of support equipment and other preparations for support activities. After the systems and their support functions are in place, user testing is accomplished. The purpose of this testing is to assure that the system performs properly in the operational environment under live conditions. The output of this stage is a formal declaration by the user that the system is ready for normal operations (Initial Operating Capability).

Operation, Maintenance and Retirement. Operation of an Embedded Computer System is the performance of its mission on a regular basis. Because operation is so readily understood we will skip discussion of operational activities. Because of the unique differences between hardware and software we must break the maintenance activities into two separate and distinct types of activities.

Hardware as a component will degrade over use and time. Mechanical parts wear out. Electrical components fail. Electrical characteristics of components may change requiring electrical adjustments and alignments. The hardware maintenance activities are to put the equipment back into the physical condition (specifications) that it was prior to the failure. This requires the use of technical data, testing equipment and a spare parts inventory.

Software does not fail in the same way that hardware fails. Software does not degrade over its use or time. It is not subject to the sudden and catastrophic failures that hardware is. One of the unique features of software is its consistency. In the operational phase the failures of software are not a cessation of the program's operation, but rather the recognition of errors which have been in the software all along. So we can say that the software maintenance activities are the correction of errors and modifications of the program to improve system capabilities. Modifications are also improvements which are necessary to upgrade systems capabilities, because of the changing operational environment. The revisions, corrections, and modifications are in essence a redevelopment through the design, code and testing processes covered previously in the Full Scale Development Phase. The Operation and Maintenance Phase for major systems usually run from 10 to 20 years in length or even longer. During this phase the system is operated and maintained, and modifications are made to update capabilities. When the system can no longer fulfill its function (mission) either through age (degradation) or not being able to keep up with changing threat, it will be considered for replacement and retirement.

The final stage of a system's life is retirement from active use either through permanent retirement or sale.

As stated earlier, one of the major obstacles to effective management for ECS has been the lack of management understanding of the complicated acquisition process. The transfer of knowledge and understanding from those who have some degree of expertise to those who do not has been almost nonexistent. The management of ECS acquisition represents a major problem within the DOD and industry.

The present educational process for DOD ECS managers is basically a learn-while-doing process. A basic understanding of the hardware/software interfaces must form the foundation for learning and improving the management of the ECS acquisition process. The Figure is a synthesis of the concepts, tasks and hardware/software interrelationships discussed earlier during the ECS acquisition process.

In all cases software activities appear to lag behind the hardware activities. Hardware decisions and activities are the driving force during most ECS acquisitions. The validation/verification testing activities are confusing and in need of clarification. This need for clarification is also indicated by the profusion of different definitions found in the literature. Only the most knowledgeable managers seem to have an appreciation for the importance of software production process.

In the past, attempts to describe and explain acquisition tasks have been overaly dependent upon emphasizing existing rules, regulations, requirements and documents to the detriment of understanding. The ECS acquisition tasks must be explained in the general terms of goals to be accomplished and how to arrive at these goals in a technical sense rather than [illegible]ing administrative requirements. Each organization has differing administrative standards, and explaining tasks in terms of one organization's requirements is not readily transferable to another organization.

In furtherance of improved management ECS costs should be broken down into hardware, software, and system costs. Hardware costs would be only those costs to develop and produce the hardware as a single entity. Software costs would be those costs to develop and duplicate the software as a single entity. System costs should be all of those costs occurring because the hardware and software are wedded together as an integrated functioning system. In other words, those costs which would not have occurred if software and hardware were not integrated into a single system. In this way the ECS acquisition process can be managed with direct task/cost accounting methods. To accomplish this task, an accounting system which will separate the costs must be developed. At present, few ECS programs have an accounting system which shows software costs.

It should be noted here that although the field evaluation shows that this model represents the current state of the acquisition process, this model is not completely adequate for today's needs. The software must be given more attention, software efforts must start earlier, and a unified systems approach must be developed for the acquisition of Embedded Computer Systems.

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AFLC INCORPORATION OF DAMAGE TOLERANCE ANALYSIS CAPABILITY

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First Lieutenant H. N. Anstine, San Antonio Air Logistics Center

INTRODUCTION

The objective of this study was to develop a plan to provide Air Force Logistics Command (AFLC) engineers with the capability to perform Durability and Damage Tolerance Assessments (DADTA) of airframe structures. An organic DADTA capability supporting AFLC's Aircraft System Managers will allow the USAF to increase safety, [illegible] manpower savings through computerized damage evaluation, decrease aircraft down time due to structural damage, reduce contract lead time, reduce contract costs, and maintain technological pace with developments in the design of sophisticated and complex weapon systems. This paper is an abstraction of the final report which was submitted to AFLC Headquarters [1].

THE DADTA CONCEPT

A DADTA is a sequence of procedures which project operational time to failure of life-limiting structural components. Decisions to extend aircraft service life may then be based on economic considerations. The DADTA process considers the sequence of loads encountered by the aircraft while performing its mission. Sophisticated computer programs are used to apply these loads to mathematical models of the structure, detect high stress areas, compute crack growth rate as a function of flying hours, and project the life of the structure. At each step, laboratory or flight test data is used to verify the analytical results [2,3,4].

Prior to DADTA a single production airframe was fatigue tested to a preset number of simulated flying hours. The service life was then computed by applying a statistically derived scatter factor to allow for dissimilarities in airframe structure and operational usage. Upon reaching this service limit the aircraft is either removed from flight or recertified by further testing. Information is a key distinction between DADTA and the earlier approach. Life limiting structures are specifically identified by DADTA and the magnitude of the effort necessary to extend the life of the aircraft may be assessed more accurately.

THE SERVICE TEST

The objective of the service test was to develop a plan to integrate a high technology analytical tool into an organization oriented toward contracted support of engineering analyses. The organizational structure within which this capability could effectively function was to be outlined. The levels of expertise and numbers of the personnel required to support the effort were to be specified. Finally, the computer configuration necessary to support the program in the systems management environment was to be ascertained. The plan was to include the recommended solution and identify all options investigated.

A three phase program with increasing commitments during each phase was conceived to meet the objectives. The capability to perform all of the DADTA procedures was developed during the first phase. The concept and power of the techniques were applied to actual systems management situations during the second phase. Implementation of the capability throughout the Air Force Logistics Command is scheduled to proceed in the third phase. This paper addresses the service test which comprises the first two phases.

PHASE ONE

The development phase initiated in the Service Engineering Division of the Directorate of Materiel Management at San Antonio Air Logistics Center. The principle objectives included documentation of requirements, identification and acquisition of computer hardware and software, training of personnel, and initiation of the T-37 and T-38 analyses.

Phase One was organized under a formalized project management concept [5]. Specialists from several disciplines were brought together in a single location under a designated project manager. The members of the team concentrated their efforts on meeting the objectives of the service test. The project manager was dedicated to the service test and reported to the third level of management in the Engineering Division structure

The Engineering Division provided analytical support to system and item managers in other divisions. Tasks were routinely transmitted between divisions at the branch level. Each branch was further divided into sections by engineering specialty. The sections were divided into units which were responsible for support of a specific aircraft system. The DADTA Service Test wa[illegible] as a section and routine tasks were char[illegible] from members of the team. This arra[illegible] effectively isolated the project from the systems support environment. The service test team included three structural engineers and one fracture mechanics specialist. The fracture mechanics specialist was also the project

manager. Experts in aerodynamics and computer engineering were part-time members of the team.

The members of the team attended several continuing engineering short courses to review principles of DADTA procedures. A 40-hour short course in finite element structural analysis was developed and presented to engineers at San Antonio Air Logistics Center on three occasions.

During Phase One an exhaustive trade-off analysis of proposed design modifications to the T-38 wing was completed. This effort included a complete analytical model of the structure. Crack growth studies were performed on a critical area of the T-38 wing using a maneuver spectrum for one of the T-38 missions. A finite element model of the entire T-37 airframe was constructed and a preliminary airloads computer model of the T-37 was developed.

PHASE TWO

The second phase of the service test began during a major reorganization of the Directorate of Materiel Management. The isolated environment of Phase One was abandoned as the team became a sub unit of the Aircraft Structural Integrity Unit in the Systems Management Division. The sub unit was given responsibility for the structural integrity programs of the T-38 and was directed to assist in supporting the structural integrity programs of all other aircraft managed by the division. Team members were also tasked to use their expertise to support accident investigations, repair analyses, and field problems. This visibility led to an increased awareness of the power of DADTA by management and by other engineers assigned to the division. As understanding of DADTA increased, the priorities of the service test personnel were extensively realigned by management. Their expertise was applied to a wide variety of operational problems and the organic DADTA of the T-37 was delayed.

The DADTA Sub Unit continued the joint DADTA of the T-38 with the contractor. Preliminary results of this effort resulted in significant modifications in the management of the T-38. Several recommended changes to the wing design were incorporated in spares purchases. A design defect was found to be more severe than anticipated when quantitatively evaluated and required that appropriate action be taken to ensure safety.

The group interacted with Non-Destructive Inspection personnel in developing and implementing inspections of critical structures. The DADTA personnel frequently acted as consultants in meetings between contractors and engineers at San Antonio Air Logistics Center. In this capacity the DADTA group became involved in engine and item management programs. Finally, the DADTA Sub Unit personnel were frequently called upon to present briefings to upper management and to visitors from outside the Center. These briefings involved a wide range of topics related to structural integrity--from general discussions of the DADTA concept to recommended solutions of specific management problems.

During Phase Two a comprehensive master plan for implementation of the capability to perform DADTA was prepared [1]. The key points of the plan are outlined in the next section.

RECOMMENDATIONS

ORGANIZATIONAL STRUCTURE

The DADTA group should be within the Engineering and Reliability Branch of the Systems Management Division. The group should be placed at a functional level that will permit support to all aircraft systems. The ideal situation would be for the group to be colocated with a centralized structural integrity unit. The criticality and technical sophistication of DADTA will not permit dispersal of the DADTA group. Such dispersal would eliminate qualified technical review of projects, since supervisors who have responsibility over several engineers with diverse specialities cannot be an expert in every specialty.

The DADTA resources will be available to all engineers at each Air Logistics Center (ALC). The DADTA team at each ALC will function independent of teams at the other ALCs. The activities of each ALC DADTA team will be monitored by the Headquarters AFLC Aircraft Structural Integrity Program office to ensure that ALC DADTA program objectives are being met.

PERSONNEL

The initial DADTA unit at each ALC will have two lead engineers. One will be a structural engineer with a finite element capability and the other will be a fracture mechanics specialist. These engineers will receive training and will oversee the implementation of the computer hardware and software systems. Once the capability is in place, the DADTA engineers will begin the education process of all system engineers associated with structures or structural integrity. One year after initiation, the lead engineers will be supplemented with project engineers as required. The lead engineers will continue to act as consultants and educators while the project engineers will provide routine support of DADTA requirements. All projects performed by the DADTA project engineers must be checked for technical accuracy by the lead engineer.

COMPUTER SOFTWARE

All computer programs used by DADTA are routinely available. Several finite element structural analysis programs are currently in use. NASTRAN, COSMIC Version, is recommended for AFLC use because of organic Air Force support. The programs SPECA, RPCM, and RSG are recommended for use in spectrum development. CRACKS IV is recommended for crack growth studies. The University of Arizona GIFTS interactive graphics package is recommended to facilitate construction and evaluation of finite ...ent models. Several other pre and post processing programs are also discussed in Reference [1].

COMPUTER HARDWARE

The computer support required for DADTA includes a large main frame computer with sufficient capacity to run NASTRAN, a remote site with a mini computer and remote interactive graphics capability, and a 4800 baud communication line connecting the remote to the central computer. The main frame computer must be located at each ALC so that prioritization of systems requirements may be maintained by the Commander of each Center. A central computer serving all Centers would result in priorities being set at AFLC level and would penalize efficient users during periods of increased requirements.

TRAINING

Three courses must be administered at each ALC. The DADTA unit will have responsibility for instructing courses in DADTA concepts, Finite Element Structural Analysis, and Fracture Mechanics. All of these courses have been prepared at SA-ALC and will be distributed to the other ALCs. Several industries and universities offer short courses in DADTA concepts and Finite Element Structural Analysis. It is highly recommended that at least one person from each DADTA unit attend both of these formal courses annually. The first level manager above the DADTA lead engineers should also attend a formal course in DADTA concepts to gain a greater perspective on DADTA potential. Reference . recommends specific courses and their lo. at .ns.

DADTA QUALITY CONTROL

Safety of flight is directly involved in DADTA projects. Repair of damaged critical airframe structure requires controls to guard against the possibility of a faulty analysis. Most repair analyses within AFLC are performed by contract. Implementing the technology and capability to perform DADTA of aircraft structures organically calls for adherence to standard project engineering quality control procedures. A lead engineer will check the technical accuracy of the analysis performed by the project engineers. Review for logistics impact, feasibility, and implementation will be provided by first level management. Approval will be granted at whatever management level is necessary for implementation of the project recommendations.

CONCLUSION

Organic DADTA is a viable concept if management is willing to support the requirements of this high technology analytical tool. An effective DADTA program must have experienced personnel dedicated to DADTA, a training program, computer resources, and a library of technical reference material. Incorporation of DADTA within AFLC will require careful evaluation of data packages acquired with future aircraft systems. The combination of organic DADTA capability and coordinated acquisition of data will significantly enhance the capability of the Air Force Logistics Command to respond to the needs of the user commands.

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NEW INITIATIVES IN SPECIFICATIONS

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The Aeronautical System Division has undertaken a new program to upgrade its methods of writing and using specifications and standards in the Research and Development environment.

This effort represents an evolution of the specifications and standards of today to meet our needs in a very fast changing technical society.

Background

Our specifications of today are, in themselves, not bad documents as many have claimed but rather are misapplied. In reality, today's specifications are written to procure a specific item. Over the years, this philosophy of the detail specification had spread into Research and Development procurements. This has been recognized by various groups as a major contributor to the high cost of military systems.

The problems associated with these documents were the application of them. A Defense Science Board Task Force reviewing this area initial findings were reported by Deputy Secretary Clements to the Military Department Secretaries: "The Task Force has concluded the content of specifications and standards is not the primary contributor to unnecessary contract costs although there is a continuing need for evolutionary improvement. The main cause of cost escalation was identified to be in the application, interpretation, demonstration of compliance and enforcement of specifications and standards in RFPs (sic: Request for Proposals) and contracts. This, therefore, is a fertile area for effective cost reductions in the acquisition process." Deputy Secretary Clements directed the Department Secretaries to "Institute Procedures and Policies to control blanket contractual imposition of such specifications and standards. These controls should be structured to force technical activities to tailor requirements to the essential specific operational needs of the end item or system." (Underliner added) The overall theme is to force tailoring and state requirements in terms of operational needs.

The Task Force recommended two steps in its April 1977 final report; an evolutionary program to improve existing specifications, and an immediate program throughout the services and industry to improve the climate of applying the specifications.

During this same time period, another examination was taking place viewing the overall budget and procurement cycle. This resulted in reforms established by the Congressional Budget Act of 1974 (Public Law 93-344) which becomes effective with the FY 1979 budget.

Within the Executive Branch, the Office of Management and Budget issued Circular No. A-109 to provide policy to all executive agencies. Circular A-109 basically requires that a request for funds should be based on a mission need rather than a specific hardware item.

Figure 1 illustrates the difference between the current system and the A-109 (mission) approach. Figure 2 shows a flow chart of how the mission approach would continue down to the various R&D projects.

In January 1976, the Aeronautical Systems Division started an effort to review its own utilization and development of military speci-

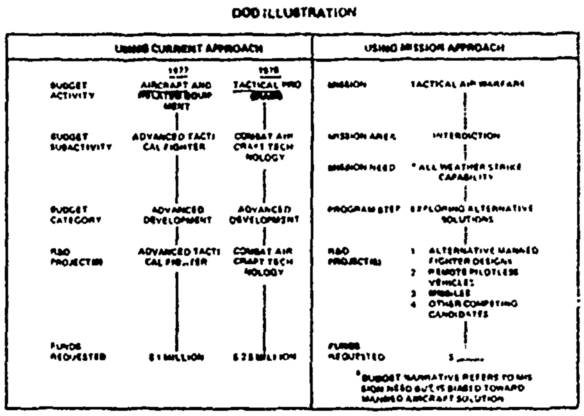

Figure 1

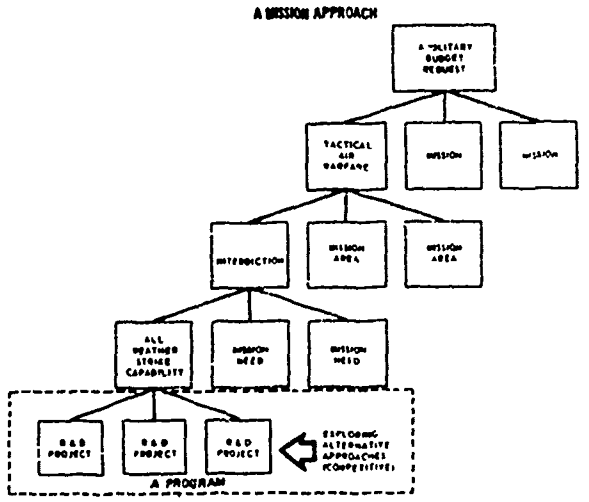

Figure 2

with the back-up rationale in the handbook.

In developing this concept, it was found that in some cases requirements within specifications could not be logically verified. In prime documents, any requirement must be verified by a corresponding verification, whether it be a test, analysis, or inspection.

Two other typical problems are trying to find the right person to ask a question on a specification; and second, finding the individual accountable for these documents. In the present system, they are "anonymous". A new facet will be the inclusion of name, address, and phone number of the individual responsible for the document, keeping it up to date, in a manner similar to the crew chief who has his name painted on the side of an aircraft.

While we have described the specifications, standards follow the same basic format; the difference being that the "standard values" appear in the document and that we are not procuring an item of hardware. In writing the primary specification, we envision only the standards as being referenced.

In practice (sic: Fig 3) the primary specification is a guide that the project engineer must now tailor. He must examine the blanks, fill in the applicable operational needs based on user input, provide interface requirements, and tailor the test section to the mission needs. This document has been designated a Type I specification, and it is a development specification stating the performance requirement for design or engineering development in terms of the operational needs. The Type I specification becomes part of the Request for Proposal. The government evaluates the contractors' proposals against this document and issues a contract. The item is then developed and after it has been found acceptable, either the contractor or government would prepare a Type II specification.

DOCUMENTATION FORMAT

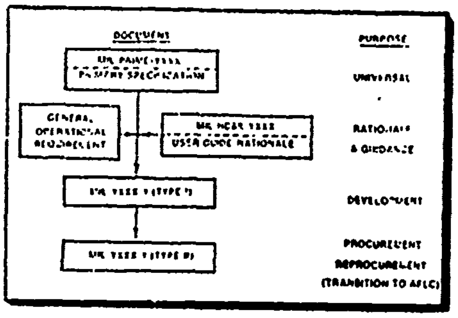

Figure 3

This is a product specification stating detail design requirements for procurement of a product in terms of specific design needs, basically what today is a military specification. It may even be possible that from one Type I specification a series of Type IIs would evolve, such as for new components that were developed as part of this effort. Today, too often we directly write the military specification (Type II). This is almost like having the answer before the question is asked.

This is not really new but is an adoption of a technique that has been very successfully used in development/reprocurement of component items, such as mircocircuits and switches within today's specification system. For some component series, a general design specification exists and in a manner they contain blanks. The blanks are stated by the term "as specified". A development document is provided by the procuring agency which states the "as specifieds". After development, a final detail specification is issued for reprocurement. The primary specification is similar to the general design document and the Type II is the same as the detail specification. One improvement is the Type I specification, which now would provide a standard bridge from the start to the final document missing in today's procurement method.

At first, this appears to increase the number of specifications and it may if we were to view the military specification system only. In reality, there are additional specification systems within the Department of Defense. In many cases today, rather than use a specification, an exhibit of MIL-STD-490 specification is prepared. A major problem exists in the 490 system. In many cases, the hardware documentation that is developed is not available to outside activities; and as a result, standardization efforts take a second seat.

With the development of a prime document in each technical area, exhibits or MIL-STD-490 documents will no longer be required. Figure 4 shows the relationship of the current specification systems to the prime system. This will result in using one baseline; the prime specifications rather than the various documentation systems in use today.

One thing this program accomplishes is to raise the level of the specification to a higher level in the procurement tree. We have been too concerned with nuts and bolts and individual items such as particular radios and radar units. The Primary Concept allows us to move up to entire functional areas such as an aircraft structure, offensive avionics, or even to categories such as auto-

fications and standards. At the time, there was no attempt to marry the specification system and A-109 budget syst m. What has evolved, however, is a systems approach to specifications in the R&D cycle that fits the objectives of A-109 and meets the long range recommendation of the Defense Science Board. While the A-109 looks towards mission approach, these specifications view mission needs and at the same time have evolved into a new document that forces tailoring. It is interesting to note in the experimental usage of this new system the tailoring philosophy has carried over from specifications into other ite[illegible] as data items and management plans.

The New Specifications

Are they new? No! But rather taking the best parts of a variety of specification systems from both government and industry and putting them into a logical, single structure.

In developing new weapon systems, our military services are facing sharply rising costs from two directions. The first is due to the highly sophisticated equipment required on the modern battlefield and the maintenance of that equipment. The second cost driver is not very visible; it's the way we write and use our specification in a world of advancing technology.

We live in a rapidly changing environment and we need documentation that is adaptable to change. Our current specification systems is not adaptable to rapid change. Consequently, it has come under repetitive attack as a major cost driver. However, every group investigating the system has generally come to the same conclusion. It is a required system, but fine tuning and slow improvements will not meet our future needs.

In various aircraft prototyping programs, ASD has found giving contractors maximum flexibility and minimum supervision has resulted in technical successes. We must apply this flexibil[illegible] to all weapon systems programs. To accom[illegible]ish this, we have developed a new series of documents called the Primary Specification, Standard, and Handbook.

The Primary Concept

This concept is aimed at new types of specifications, standards, and handbooks. these new documents are written for the contractor and for the government to provide guidance and set the framework to build specifications for product development as well as fo[illegible] the actual procurement cycle. The objectives of these new documents are to "force tailoring" and specify operational needs, and at the same time, improve other facets of the m[illegible] [illegible] specification program. This system will consist of three types of primary document; specifications, standards, and handbooks The primary specification (Mil-Prime) are aimed at specifying operational needs and general parameters for a physical product family with the specific values left blank. The primary standard (Mil-Prime-Std) provides the criteria and qualities applicable to a physical product but is not used to procure any actual product, and in many cases is very similar to our standards of today. The primary handbook (Mil-Prime-Handbook) contains technical rationale for the requirements stated in each primary specification and standard, provides guidance for applying the specifications and standards, and is a depository for lessons learned in each technical area. We would not develop a primary document for each individual product or service; this would just duplicate the 44,000 military specifications and standards in today's system. Instead, a broad family grouping will be established. These Mil-Prime product families will cover such areas as airborne radios, fasteners, parachutes, landing gear, or the entire aircraft structure.

The prime standards basically encompass the "ilities" (reliability, maintainability, etc) as well as "standard test methods" or "climatic extremes". The handbooks will explain where a requirement came from and why we require it for both the specifications and standards.

These "Mil-Prime" document[illegible], with the operational values blank, will for[illegible] tailoring. They also provide a depository for "corpor[illegible] memory" and will allow others to question [illegible] requirements based on facts. No longer can anyone say "you must do it this way because the specification says so", and so the argument ends. Now the argument must rotate about the rationale contained in the handbook....a logical point of departure. As new lessons are learned and technology changes, the handbooks will be updated.

As the specification is used, the blanks are filled in by the project engineer. [illegible] handbook assists in this filling-in proc[illegible] by showing [illegible]ow [illegible] fill in the blanks and, most importantly, the rationale for the requirements

Of course, these documents are not just blanks. A closer look at the primary specification would show not only blank operational needs, but in addition, a section on interface would be provided. The project engineer would provide detai[illegible] [illegible] requirement such as a size of a bay, [illegible] number, even available power and typ[illegible] [illegible] details on government furnished equipment. [illegible] the technical community, we have standardized values, such as safety factors. These would be maintained within the documen[illegible] [illegible]

SPECIFICATION/STANDARD PERSPECTIVE

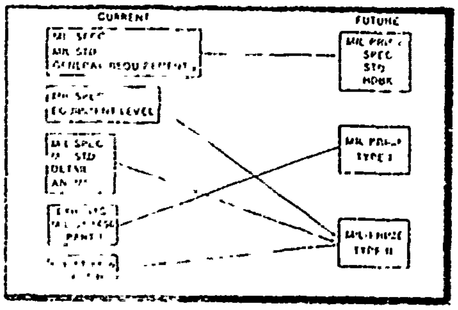

Figure 4

matic test equipment and simulators. Within the Department of Defense, this method has been very successfully utilized at the component level. For higher order procurements, this same concept can be used. These are the areas the Air Force program is attacking. With experience, it may even be possible to view whole systems such as the air vehicle or support equipment.

This new concept also offers the Department of Defense with an opportunity to develop a new numbering system for specifications. Today's system is based on allocation of numbers to branches and assignment thereafter in numerical order. This does not facilitate data retrieval or provide a convenient method to trace known products to avoid duplication. One suggested approach has been that each primary specification area be assigned a number. The handbook would have the same number. The Type I and Type II specifications would be issued an additional number to the basic prime number such as a dash number. In areas where the primary document covers a broad technology, additional coding may be necessary. The end objective is to provide a numbering system that would allow easy examination of all products already available within DOD that have been developed within any one class. When we combine this new numbering system with all types of specifications in one system, we also move forward in achieving another important goal - standardization. This is accomplished by putting at the designers' fingertips what is available in a logical order not only what is in the current system, but also the MIL-STD-490 specification that today would have been left out. For example, let us assume we want to use a blind rivet on an aircraft. The primary area would be fasteners, and we would have additional coding for bolts, nuts, screws, rivets, etc. The end number is shown in Figure 5.

On the whole, the number of development specifications will decrease and the number of detail specification will remain the same. But we <u>will</u> know where things are, and what has been developed with DOD. This in itself will be a vast improvement.

In viewing standardization we must remember that the amount of standardization is a management decision. The specification and standards only serve as a catalog of what is available. Utilization of the new numbering system will improve standardization by providing a better picture of what is available.

At this point, we have discussed the Primary Concept and what it does accomplish. The movement to operational needs will allow different contractors to bid different solutions to a particular problem rather than solving the mechanics of single solution as described in so many of today's specifications. The end result will be a better product more responsive to the user's needs. It will encourage innovative design and, at the same time, reduce gold plating, because so many of the "cover your ____" (fill in the blank) documents will no longer be thrown on the stack of specifications. Another point in this area is the forced tailoring which will contribute very strongly to meeting these objectives. The concept of broad primary documents will have an effect of reducing tiering or

MI - PRIME - 2068 - 27 - XXX

2068: Fastener Area

27: Rivet Aircraft

XXX: All Rivets would follow in sequence

Figure 5

references from one document to another. This will contribute cost savings in the long term as well as a reduction in paper work. It also removes problems where one referenced document conflicts with another referenced document.

One document that has lingered in the background of this discussion is the handbook. Not much has been said other than it will provide the rationale and instructions for the specifications and standards. If we examine this new document carefully, we can find that it is one of the most important aspects of this program. Today, we do not have a true depository in each technical area to retain our lessons learned. These handbooks would fulfill this need. In viewing the rationale behind requirements and criteria, these may change when conditions or state-of-the-art progresses. Today, changes to criteria can be very difficult to effect when you do not know why a factor was established 30 years ago. It will also open up our rationale to the public for our requirements, adding an important check and balance that is missing today. It will allow us to apply the lessons learned from one weapon system to another since we are using the "same specification". Only the blanks change and give us the same baseline for different programs.

How does the government engineer fit in? First, for each primary document, there will be known focal points. We project him to be a busy man maintaining the handbook for his specification or standard. In the real world, we foresee very little change to the specification or standard; but constant change to the handbook. The engineer with the procurement team will be required to fill in the blanks and prepare the Type I specification. This is a prelude to an extremely hard task, that of source selection. Determining if a proposed solution can be accomplished as stated and its potential for success will not be a simple task and will require the highest degree of professionalism on the part of the government engineer. After selection and development, the operational test program will provide the engineer with another challenge.

How does this affect the contractor? He now has latitude to truly design a solution within his area of expertise. But on the other side of the coin, he must now take a total systems approach. The handbook gives him a baseline to depart from. In meeting the needs of the Air Force, his responsibility has vastly increased.

Is this concept a dream? No! The Aeronautical Systems Division's (ASD) Deputy for Engineering, under the direction of the Air Force Systems Command and Headquarters, United States Air Force, is already moving into this program with an impressive set of primary specifications being prepared. These include electronic countermeasures equipment, landing gear, parachutes, and airframe structures. Some of these documents are going to take almost two years to develop. This is not an easy task. When the program will be finished in 1981-82 time frame, ASD will have less than 100 documents. The Department of Defense (DOD) is viewing this effort to determine if it can be applied to all DOD agencies. Success at ASD may result in change throughout the entire military establishment.

While these new documents are being prepared, the overall philosophy is being used in development of current system specifications. The F-16 and YC-14/YC-15 aircraft are using this concept in their procurement. Further, many individual equipment items will be procured in this manner. Initial findings in use of this concept to the CX-1 program (YC-14/YC-15) show significant improvements in its use. In the case of this program, both contractors have found savings in being able to respond to an operational need. For example, the RFP does not have a fastener specification, but rather views the aircraft mission. Both contractors have approached the fastener design from a different standpoint; and in both cases, the cost savings were in the range of the cost of one aircraft in this program.

Both contractors have indicated that the procurement and specification methods used in this program have saved $50-75 million (actual data not releasable as program is still under source selection).

Summary

Over the past years, the Department of Defense has tried many different procurement techniques. It seems that many of these techniques have not resolved our procurement problems. A major contributor to these problems has been the application of specifications. The specifications have been a common denominator over the years and possibly these documents have been the problem.

The Mil-Prime program in combination with A-109 offers an opportunity to provide a meaningful procurement system. We have also found the tailoring philosophy of the Mil-Prime concepts has flowed to data items and management plans in their use on a particular program.

The Mil-Prime Program is new, and ASD's testing of the new system will result in fine tuning over the next few years. Results so far indicate this is a viable approach to vastly improve our procurement of new systems.

DATA SOURCES FOR ACQUISITION RESEARCH

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COMPUTER-ENHANCED LAW-ORIENTED RESEARCH

Lieutenant Colonel Michael E. Murphy, Federal Legal Information Through Electronics

INTRODUCTION

Federal Legal Information Through Electronics (FLITE) is a service organization. It harnesses computer technology to assist in law-oriented research. Its services are available to the entire federal government. Its charter appears in Department of Defense (DOD) Directive 5160.64, Federal Legal Information Through Electronics (FLITE), dated 9 October 1974.

ORGANIZATION AND MISSION

The DOD General Counsel provides policy guidance for the administration and management of FLITE. The Department of the Air Force serves as executive agency for DOD. The Secretary of the Air Force has delegated to The Judge Advocate General, United States Air Force, the duty to operate FLITE. FLITE is operated in the Gilchrist Building at Lowry Air Force Base, Denver, Colorado, as a detached Executive Services component of The Judge Advocate General's Office. It is headed by the Chief of FLITE and has three major functional areas: Administration and Resource Management, Electronic Data Processing, and User Services.

The FLITE mission is to:

- create and maintain data bases consisting of legal information for use in law and related fields;
- provide computer search services for all established data bases;
- produce special computer products;
- provide advisory service to federal, state, and local government agencies on computerized legal information research.

HOLDINGS

FLITE maintains the following computerized, full-text data bases:

- U. S. Constitution
- U. S. Code
- U. S. Code of Federal Regulations
- U. S. Reports
- U. S. Supreme Court Reporter
- Federal Reporter 2nd Series
- Federal Supplement
- Decisions of the U. S. Comptroller General (published and unpublished)
- Armed Services Procurement Regulation
- U. S. Court of Claims Reports
- Court-Martial Reports
- Manual for Courts-Martial
- International Agreements of Special Interest to DOD (published and unpublished)

The following data bases are scheduled for addition in 1978:

- Public Laws and Reorganization Plans appearing in U. S. Statutes at Large
- Opinions of the U. S. Attorney General
- Bevans (international agreements) Series
- U. S. Treaties Series
- Federal Reporter 1st Series
- Legislative Histories and Executive Orders appearing in U. S. Code Congressional and Administrative News
- Opinions of The Judge Advocates General of the Armed Forces
- Decisions and Reports on Rulings of the Assistant Secretary of Labor for Labor-Management Relations, Pursuant to Executive Order 11491
- Decisions and Interpretations of the Federal Labor Council
- Rulings on Requests for Review of the Assistant Secretary of Labor for Labor-Management Relations, Pursuant to Executive Order 11491, as Amended
- U. S. Tax Court Reports
- Board of Tax Appeals Decisions

PUBLICATIONS

FLITE has published a pamphlet, FLITE: Legal Research For You, and each quarter publishes the FLITE Newsletter, Air Force Recurring Publication 110-3.

INFORMATION SERVICES

FLITE User Services attorney-advisors have access to the FLITE data bank and to the Justice Retrieval and Inquiry System (JURIS) data bank. These attorney-advisors provide computer search information based on user requests. Authorized users include all entities of the federal government. Search services are provided without fee to the Office of the Secretary of Defense and all DOD components (including the U. S. Coast Guard), the Executive Office of the President of the United States (including the Library of Congress), and the U. S. Supreme Court. All

other authorized users are charged $50.00 per data base searched.

Special computer products include cross-reference digests, citators, key-word-in-context (KWIC) indexes, etc.

Advisory services are provided to federal, state, and local government agencies on problems related to computerized information research.

USER CONTACTS

No requirement exists for users to be familiar with computer search strategy. About 70 percent of search requests are made by attorneys. The remainder come from professionals in allied fields, such as procurement/acquisition; fiscal administration, transportation, and personnel. Contact is made with FLITE User Services by telephone, electrical message, interview, or letter. Discussion between the user and a FLITE User Services attorney-advisor before a search is made is recommended.

The FLITE key staff consists of:

	Telephone Extension
CHIEF OF FLITE	
MURPHY, Lt Colonel Michael E., Chief, FLITE	7531
MC CLELLAN, Mrs Edith I., Secretary	7531
ADMINISTRATION AND RESOURCE MANAGEMENT	
RUSSELL, Mr Robert S., Jr., Chief	7535
CRABTREE, Ms Jennie R.	7535
ELECTRONIC DATA PROCESSING	
HOWERTON, Mr Charles P., Chief	7535
VOELKEL, Mr Edward, Lead Computer Programmer	7535
EASTER, Mrs Vivian J., Supervisory Computer Technician	7535
USER SERVICES	
BERTHELSEN, Mr Alvin L., Chief	7531
DUCKWORTH, Mr Edward "	7531
BIBBY, Mr Ronald J.	7531
LUNDWALL, Mr Robert E.	7531
UNTERSPAN, Mr James H.	7531
SKINNER, Mr James T.	7531

The telephone accesses to FLITE are:

COMMERCIAL	(303)	320-ext.
AUTOVON		926-ext.
FTS		326-ext.

The electrical message address for FLITE is: FLITE LOWRY AFB CO

The mailing address for FLITE is: FLITE
Denver CO 80279

Although the library is now working on increasing the book portion of the collection, volume-wise books will always be a minor part of its holdings. Traditional, hard-bound books on contracting and related subjects are relatively scarce; however, this is not the case for the additional subjects now being incorporated in the collection. Due to the short shelf life of information in this field, the growth in the library's holdings will be concentrated in the report literature section. It is through the reports, theses, conference and seminar proceedings, and journals that most new ideas are presented, criticized, refined and disseminated to colleagues. A highly specialized collection of this type requires non-traditional methods for acquiring, organizing, cataloging, and circulating its materials. Therefore, the FAI library is already a non-traditional research center, and it plans to become even more so in the future.

Satisfying user needs and requirements is the "raison d'etre" of any worthwhile library, especially one whose chief patrons are engaged in research and management. Although still in the process of determining the full extent of the informational needs of the Office of Federal Procurement Policy, the FAI member agencies, and the rest of the acquisition community, the library's initial effort to facilitate the transfer of information has proven quite successful. On a bi-monthly basis, the library compiles and issues an in-house publication entitled Procurement Literature Abstracts, which gives a brief description of selected articles appearing in journals received in the library. Originally developed for the use of OFPP and FAI staff members, it is now distributed to over 400 individuals throughout the Federal acquisition work force, private industry, law firms, and educational institutions. In its current format, the Abstracts is a modest, relatively informal attempt to record the burgeoning amount of information being produced in acquisition and assistance and hopefully it will serve as the springboard for a more extensive future effort which can be captured in machine-readable form.

Providing bibliographic services is another user-oriented capability of the library. Upon request, and with sufficient advance notice, bibliographies are compiled on subjects selected by the user. For instance, a bibliography on pre-World War II procurement and one on government contract disputes were furnished to the Congressional Research Service of the Library of Congress, and a bibliography on Federal acquisitions was recently compiled for the Subcommittee on Federal Spending Practices and Open Government of the Senate Committee on Governmental Affairs. At the present time, due to limited personnel and financial resources, this service is available only to government agencies.

As an additional resource for its users, the FAI library is considering organizing and maintaining a repository for education and learning materials in Federal acquisition and assistance (1). Such a collection would be composed of textbooks, instructors' guides, curricula plans, and audio-visual aids from both public and private institutions. Since these sources often include narrow subjects not covered elsewhere and emphasize the state-of-the-art in those subjects, researchers should find it advantageous to have all the material grouped together in one location. Nevertheless, plans for the learning materials repository are still in the developmental stage.

FUTURE PLANS

In all probability, the role of the FAI library in the future will be influenced by two rapidly emerging developments -- the computer and library networks. Though separate and distinct elements, one being physical and the other conceptual, they are on the path to becoming interactive and mutually beneficial. The computer is an information storage and communication device; networking is a management and logistics principle by which library resources, such as computers, are shared by many. Coordinating the two developments into computer assisted library networks will be of profound significance to all researchers.

The computer has three basic applications in the library; bibliographic control, document reproduction and distribution, and information retrieval (5:316). So far most studies and implementations have been concentrated in the first two applications. Operators of a computer system search titles in a data base and deliver to the requestor one or more of the documents selected. Most of these systems are off-line and are queried by a trained search strategist, not the requestor. An off-line system must rely on conventional delivery methods, mostly mail service, to relay the search results to the requestor. This delivery system is the weakest link in the chain of information transfer. Since off-line systems fail to allow interaction between the requestor and the data bank, and since the response time is not immediate, the searches are often not properly refined and focused to be as productive as possible. For these reasons, the relatively recent development of on-line systems marks the most important advance in information dissemination in the past decade. The capability of an on-line system for immediate search and display and user/computer interaction make it the key information retrieval device of the future.

THE FEDERAL ACQUISITION INSTITUTE LIBRARY: TODAY AND TOMORROW*

Helen T. Hertel
Librarian, Federal Acquisition Institute

Information dissemination is an integral part of acquisition[1] research and development; communicating what is already known to those who want to know is essential in helping to reduce the number of times the wheel is reinvented. The volume of information and the diversity of its sources necessitate the existence of a specialized information center to serve the needs of those working in the Federal acquisition and assistance field. One unit must be responsible for identifying, locating, acquiring, organizing, storing and disseminating the information gleaned from the ephemeral and fugitive materials[2] which abound in this discipline. Most of the information is produced not in book form, but in journals, conference proceedings, research reports, student papers, handbooks, correspondence, and memoranda -- most of which have limited distribution. To add to the problem of identifying and locating acquisition materials, the standard literature indexing and abstracting services barely scratch the surface in this subject area. It is impractical and nearly impossible for the individual researcher to cope with these problems. Hence, the need for the Federal Acquisition Institute (FAI)[3] Library to function as a specialized information center in Federal acquisition and assistance.

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* Opinions expressed herein are the responsibility of the author and are not to be interpreted as official FAI policy.

1/ Broadly defined, the term "acquisition" encompasses contracting and contract administration, quality and reliability assurance, systems acquisition and program/budget management, and logistics.

2/ Ephemeral and fugitive materials are those documents issued outside regular publishing channels and usually known only to a relatively small number of people. Abound and uncontrolled, they are unavailable forever unless obtained from the source immediately upon release.

3/ Originally named the Federal Procurement Institute, the agency was renamed the Federal Acquisition Institute effective March 1, 1978 by a vote of the Policy Board. For uniformity, the current name will be used throughout this article regardless of time frame.

BACKGROUND

The idea for a specialized collection in this field was born in the Commission on Government Procurement. The Commission members, realizing the permanent value of the background papers and supporting documents which they had gathered, arranged for the General Services Administration to maintain the collection intact from the termination of the Commission until the establishment of the Federal Acquisition Institute. In addition to their recommendation for the creation of the Institute, the Commission strongly advised that the COGP collection be considered the nucleus of a central repository in acquisition and assistance to support the research function of the FAI and to serve the information needs of the entire acquisition community (6:52). Under this arrangement, the library was operated by GSA's Federal Supply Service in Crystal City, Virginia for the period April 1973 to August 1977.

When the Federal Acquisition Institute became operational in September 1977, the library moved to its present location in the FAI offices at 5001 Eisenhower Avenue, Alexandria, Virginia. Now that the library's origins have been briefly related, the remainder of this article will focus on the present and future role of the FAI Library as a specialized information center.

CURRENT STATUS

The library is a vital and active participant in FAI's mission to promote acquisition research and to develop and monitor acquisition education, training and career development. In keeping with this function, the library will continue to concentrate its material gathering efforts in Federal acquisition and assistance, but will also add education, training, personnel, and business research and management as supplemental subjects.

At present the library's unique collection consists of approximately 300 books; 5200 reports, theses and proceedings; 60 journals and looseleaf services; 22 file cabinets of COGP back-up material; congressional hearings, reports and bills; and a legal section, including the U.S. Code, U.S. Code Annotated, Board of Contract Appeals decisions, Comptroller General decisions, the Code of Federal Regulations, the Armed Services Procurement Regulation, Federal Procurement Regulations, and various other [illegible] regulations, directives and circulars.

Though clearly a desirable method of information storage and transfer, computer systems are nevertheless quite expensive. In view of ever increasing budget, staff, and space constraints, computer use would almost seem beyond the reach of the smaller, specialized libraries, educational departments and commercial firms. However, a solution lies in the concept of resource sharing networks. With libraries now being forced to abandon the traditional doctrine of complete self-sufficiency and to place more emphasis on access rather than possession, maximizing the availability of materials and services and minimizing expenses is one of the fundamental goals of resource sharing (4:[illegible]).

The information needs of the acquisition/assistance community will be met most satisfactorily if, over the next several years, all libraries in this field form a resource sharing network. At present the libraries of the Defense Systems Management College, the Army Logistics Management Center, the School of Systems and Logistics at the Air Force Institute of Technology, and the Naval Postgraduate School agree, on an informal basis, to share some resources. Most of this cooperation is in the form of assistance in identifying and/or locating a publication and short-term borrowing of materials. Although this approach is adequate now, it will not be adequate in the future as the volume of information proliferates.

Under the auspices of the Research Directorate, the Federal Acquisition Institute is planning to study the feasibility of "implementing a collecting, cataloging, and indexing system in terms of computer hardware and software, time sharing, terminals, data and documents, and users to be serviced" (1). It is envisioned that the entire holdings of the FAI library, as well as those of other interested libraries, will be included in this data bank as one method of coping with the amount of information forthcoming.

Recent visits to other libraries having some interest in the Federal acquisition and assistance fields indicate that no other library concentrates exclusively in this highly specialized subject area. Being primarily book-oriented, they are unable to cover the subject in depth since, as mentioned earlier, written communication regarding acquisition appears mostly in non-book form. As most of these other libraries are part of educational institutions, their report literature is often limited to the studies and theses conducted by their own students. In other subject categories they are far stronger than the FAI library; but in Federal acquisition and assistance, the FAI library has more subject depth and a greater variety in types of material sought and retained.

A large percentage of the acquisition community does not have access to these other scattered collections. Libraries belonging to military educational institutions and to civil agency headquarters serve only their own students and/or staff. While some material does pass between military and civil agencies through interlibrary loan, this procedure is not encouraged. Furthermore, although almost every civil agency has a procurement activity, only one has a library which collects some material in this subject. Also, there is a very significant number of individuals outside the Federal Government who do not have recourse to the services of the military or civil agency libraries. Lawyers, state and local purchasing agents, industry officials, consultants, and independent researchers concerned with the business of Federal acquisition and assistance need to have ready access to information in the area. Additionally, many potential users are too geographically removed from these other libraries to be served by them.

Obviously, there is a real need for one library that can meet the informational requirements of all those concerned with Federal acquisition and assistance. Users require a library which is devoted exclusively to monitoring this one subject area, which gathers all available information regardless of its physical nature, and which is mandated to serve all interested parties. The FAI library is investigating the possibility of becoming such a facility. With all of its energy focused in this effort, it would benefit the acquisition community by centralizing the sources of information and it would benefit other libraries by eliminating one of the areas which their stretched resources might be required to cover.

This type of resource sharing would constitute a star network, whereby "one participant holds substantially all the resources to be utilized by other participants" (4:28). In this instance, the FAI library would hold the substantial amount of material available in acquisition and assistance, to be accessible to and utilized by all other libraries and interested individuals. Within this framework, the various considerations and approaches that would characterize the network are too numerous to detail at this time. Suffice it to say there is enough flexibility in the concept to accommodate the interests of all participating members.

Of course, having the FAI library serve as the lead library in a resource sharing network is only one potential route to consider. Another possibility is the formation of an "equally distributed network" in which "all participants hold equal (but different) quantities of material to be utilized only

by participants." (4:28). Although perhaps more difficult to administer, this type of network also has several advantages. Additional alternatives for the FAI Library's role in the information gathering process of the future are presently being explored. The final format is not likely to crystallize for quite a while.

Regardless of the type of sharing ultimately implemented, resource enhancement will be the unquestionable result. And, particularly if computer services are one of the shared components, this writer's first long-range goal for the FAI Library becoming truly an information dissemination center will be achieved.

For now, it is a library--though already a nontraditional one in many aspects. Its strongest points are these: (1) it has a firm foundation in the subject field, albeit the necessity to acquire some materials missed during the transition year in 1977; and (2) it is willing to serve everyone across the entire spectrum comprising the acquisition community, regardless of employment affiliation or geographic location.

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